

# **Brown Cloud Assessment Tool (BCAT) Version 1.0**

## **Users Guide and Technical Reference Manual**

**Developed to Support the Deliberations of  
The Governor's Brown Cloud Summit**

**Prepared for  
The Arizona Department of Environmental Quality**

**By  
The Kendall Group, Inc.**

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The development of the Brown Cloud Assessment Tool (BCAT) for the Governor's Brown Cloud Summit (Summit) was a team effort. The hard work and thoughtful contribution from many individuals allowed The Kendall Group, Inc. to assemble a decision support tool that met the assessment needs of the Summit. The Kendall Group, Inc. wishes to acknowledge the following contributions.

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## **EXECUTIVE SUMMARY**

This document serves as a reference for the Brown Cloud Assessment Tool (BCAT) and the developer's version of the BCAT (BCAT\_DEVELOPER). The BCAT is a complex Excel workbook model consisting of 39 worksheets or "Tabs" (62 in the BCAT\_DEVELOPER) that convert assumptions about the emission effects and costs of control option scenarios into projected improvements in visibility and cost effectiveness of the improvement.

The BCAT was developed by The Kendall Group, Inc. to support the deliberations of the Governor's Brown Cloud Summit (Summit). The Summit was formed by Arizona Governor Jane Hull to investigate the urban visibility problem, or brown cloud, in the Phoenix metropolitan area. The Summit examined potential causes and remedies to the issue.

The computational framework in BCAT is derived from comparable work performed by the Grand Canyon Visibility Transport Commission (GCVTC) in their examination of control strategies to remedy existing and prevent future impairment of visual air quality at the 16 mandatory Federal class-I areas (National Parks and Wilderness Areas) on the Colorado Plateau. The data used in the assessments is from more recent studies than that used by the Commission, consistent with the study area and types of policy questions to be examined.

The BCAT generates projections of emission and visibility changes associated with control option scenarios being assessed by the various Summit committees. These changes are relative to a Baseline Forecast Scenario (BFS) that includes consideration of the projected growth in population and economic activity, retirement of older sources, and the control requirements for new and existing sources under current federal, state, and local regulations. The BCAT was modified on January 10, 2001 so the Baseline Forecast Scenario would reflect the recent announcement of final EPA Tier-II diesel and heavy-duty gasoline engine and fuel standards. The BCAT generates a cost effectiveness index for the scenario, expressed in levelized annual cost per unit change in visibility (\$million/deciview), a useful metric for comparing various control option scenarios.

Section 1 provides an overview of the assessment methodology utilized in the Brown Cloud Assessment Tool (BCAT Version 1.0) developed for the Governor's Brown Cloud Summit intended for the non-technical policy maker. Section 2 provides an explanation of how to use the BCAT tool for the technical policy analyst. Section 3 provides background on the technical / policy data foundations and assumptions of the BCAT, while Section 4 explains the computational process. Finally, Section 5 provides the system developer with an explanation of how to modify or enhance the BCAT and additional technical information. For ease of cross reference, the worksheet "Tab" name in the workbook corresponds to the section number in this document that describes the content and calculations performed in the Tab.

## **TABLE OF CONTENTS**

1.0	Overview of Assessment Methodology .....	1-1
1.1	Background .....	1-1
1.2	Role of the Baseline Forecast Scenario.....	1-1
1.3	Defining a Control Option Scenario .....	1-3
1.4	Basic Computational Approach .....	1-4
1.5	Control Option Scenario Assessment Report .....	1-6
1.6	Interpretation of Results.....	1-7
2.0	Using the Assessment Tool.....	2-1
2.1	Summary Report Content and Interpretation .....	2-1
2.1.1	Control Option Scenario Description.....	2-1
2.1.2	Visibility Projections for the BFS and Control Option Scenarios .....	2-1
2.1.3	Projected Changes in Emissions .....	2-2
2.1.4	Projected Changes in Visual Air Quality .....	2-3
2.1.5	Projected Costs (Capital, O&M, Annualized) .....	2-3
2.1.6	Cost Effectiveness (\$/deciview change) .....	2-3
2.2	Organizing Data for a Control Option Scenario .....	2-4
2.2.1	Source Sector Input Data Worksheet .....	2-4
2.2.2	Source Sector Data Entry Control List.....	2-5
2.3	Entering Control Option Scenario Data Into the BCAT .....	2-5
2.3.1	Process and Tips for Entering Control Option Scenarios .....	2-6
2.3.2	Control Option Scenario Title and Description .....	2-6
2.3.3	Control Option Scenario Growth/Retirement Rate Adjustments.....	2-7
2.3.4	Control Option Scenario Existing Source Control Efficiency Adj. ....	2-8
2.3.5	Control Option Scenario New Source Control Efficiency Adj. ....	2-8
2.3.6	Control Option Scenario Emission Forecast Adjustment .....	2-9
2.3.7	Control Option Scenario Capital and Operating Costs .....	2-9
2.3.8	Printing Results and Auditing .....	2-9
2.4	Assessing Multiple Sector or Combined Scenarios .....	2-10
2.5	Comparing and Ranking Scenarios.....	2-10
3.0	Key Baseline Input Data and Control Tables.....	3-1
3.1	Analysis Years and Seasonal Considerations .....	3-1
3.2	Financial Conversion Factors (Annualized Cost, Present Value).....	3-2
3.3	Source Sectors Included in the Analysis .....	3-2
3.4	Visibility Emission Inventory Pollutants and Aerosol Species.....	3-3
3.5	1995 MAG Emission Inventory .....	3-4
3.6	Source Sector PM-2.5 Emissions Inventory Speciation Factors.....	3-4
3.7	Source Sector Overall Growth Rate Assumptions.....	3-5
3.8	Source Sector Retirement Rate Assumptions for Existing Sources.....	3-6
3.9	Baseline Control Efficiencies for Existing and New Sources.....	3-6
3.9.1	Baseline Control Efficiencies for Existing Sources .....	3-6
3.9.2	Baseline Control Efficiencies for New Sources.....	3-7

3.9.3	Derivation of Baseline Control Efficiencies .....	3-8
3.10	Air Quality Transfer Matrix / Extinction Efficiencies .....	3-8
3.10.1	Air Quality Transfer Coefficients and Background Values .....	3-9
3.10.2	Light Extinction Efficiencies and Relative Humidity .....	3-10
3.11	Intensity Index for Sensitivity Studies .....	3-10
4.0	Key Calculations and Results .....	4-1
4.1	Baseline Forecast Scenario (BFS).....	4-1
4.1.1	Baseline Projected Utilization of Existing Sources .....	4-1
4.1.2	Baseline Projected Utilization of New Sources .....	4-2
4.1.3	Baseline Projected Emissions for Existing Sources.....	4-2
4.1.4	Baseline Projected Emissions for New Sources .....	4-2
4.1.5	Baseline Projected Total Emissions.....	4-3
4.1.6	Baseline Projected Speciated Emissions.....	4-3
4.1.7	Baseline Projected Aerosol Concentration .....	4-4
4.1.8	Baseline Projected Visibility (Light Extinction).....	4-4
4.2	Control Option Scenario .....	4-5
4.2.1	Control Option Scenario Adjusted Utilization of Sources.....	4-5
4.2.2	Control Option Scenario Adjusted Control Efficiencies .....	4-6
4.2.3	Control Option Scenario Projected Emissions for Existing Sources .....	4-7
4.2.4	Control Option Scenario Projected Emissions for New Sources.....	4-7
4.2.5	Control Option Scenario Projected Total Emissions .....	4-7
4.2.6	Control Option Scenario Projected Speciated Emissions .....	4-8
4.2.7	Control Option Scenario Projected Aerosol Concentration.....	4-8
4.2.8	Control Option Scenario Projected Visibility (Light Extinction) .....	4-9
4.2.9	Control Option Scenario Emission Change Detail .....	4-10
4.3	Comparison of Control Option Scenario to Baseline Forecast .....	4-10
4.4	Audit Sheet.....	4-10
5.0	Enhancing and Maintaining BCAT: Developer's Version .....	5-1
5.1	Worksheet Layout Master Sheets.....	5-1
5.2	Data Import Sheets.....	5-1
5.2.1	Import MAG 1995 Base Inventory .....	5-2
5.2.2	Import Source Sector Overall Growth Rate Assumptions .....	5-2
5.2.3	Import Source Sector Retirement Rate for Existing Sources.....	5-2
5.2.4	Import Source Sector PM2.5 Speciation Factors .....	5-3
5.3	Control Efficiency Development Sheets.....	5-3
5.3.1	Reference Inventories (2003-2020).....	5-3
5.3.2	Assembled Baseline Reference Inventory.....	5-4
5.3.3	Implied Control Efficiencies from Reference Inventory.....	5-4
5.3.4	Inventory Adjustment for Effects of Tier-II Standards .....	5-5
5.3.5	Implied Control Efficiencies with Tier-II Standards.....	5-6
5.3.6	Imported Source Sector Control Efficiencies (2010-2020) .....	5-6
5.3.7	Spliced Control Efficiencies (Tier-II and MAG Import) .....	5-6
5.3.8	Control Efficiencies with Manual Adjustments for Consistency.....	5-6

5.3.9	Frozen Control Efficiencies for Application and 2001 Tier-II Adjustment .....	5-7
5.3.10	BFS Audit for 1995, 2003, and 2006 Emissions and 2001 Tier-II Standards .....	5-7
5.4	Creating BCAT from BCAT_DEVELOPER.....	5-8
6.0	References.....	6-1
APPENDICIES .....		A
Appendix A – Example Control Scenario .....		A

## **1.0 Overview of Assessment Methodology**

This section provides a non-technical overview for policy makers of the assessment methodology utilized in the Brown Cloud Assessment Tool (BCAT Version 1.0). Section 2 of this report provides an overview of the assessment tool intended for the technical policy analyst. Section 3 provides background on the technical / policy data foundations and assumptions of the BCAT, while Section 4 explains the computational process. Finally, Section 5 is designed to assist the system developer wishing to modify or enhance the BCAT and provides additional technical background on the computational methods.

### **1.1 Background**

On March 15, 2000, Arizona's Governor Jane Hull established the Governor's Brown Cloud Summit by executive order. Governor Hull charged the Summit to examine various technical and policy issues related to the significant visibility degradation that takes place in Phoenix due to air pollution and to recommend what options, if any, should be taken to remedy this visibility impairment. In response, the Summit established an Inventory Technical Assistance Group (ITAG) to review technical and policy assessment options and to bring back recommendations on data and on procedures to assess control option scenarios. The Summit adopted the analytical framework outlined in this document based on the recommendations of ITAG. The Arizona Department of Environmental Quality commissioned The Kendall Group, Inc. to construct the Brown Cloud Assessment Tool (BCAT) for use in the Summit's assessment work.

The BCAT analytical framework follows closely that utilized by the Grand Canyon Visibility Transport Commission. The Commission's Integrated Assessment System (IAS) offered a framework for the examination of the various control option scenarios that the Commission considered in its deliberations. The Commission's recommendations became the basis for a substantial part of the Regional Haze Rules adopted by EPA in July 1999 to protect visibility in the national parks and wilderness areas. Thus, the analytical framework for the BCAT parallels the work of a very well respected and thoroughly reviewed visibility assessment methodology.

The following is a summary of the key aspects of the analytical framework adopted from the Grand Canyon Visibility Transport Commission work for use in the BCAT.

### **1.2 Role of the Baseline Forecast Scenario**

A reference point is needed to assess the potential impact of a control option scenario, and this reference point upon which future impacts are projected is referred to as the "Baseline Forecast Scenario" or BFS. The Baseline Forecast Scenario is intended to represent the expected changes in emission patterns over time associated with economic development and the impact of other pollution control actions required under existing Federal and Arizona air quality programs. The Baseline Forecast Scenario, for the

purpose of assessments, is assumed to be a zero cost option (i.e., no costs beyond those required for other air quality requirements are expended). Thus the assessment of a control option scenario assumes the Baseline Forecast Scenario as the initial point of departure in terms of control effects and costs.

The Baseline Forecast Scenario is constructed from:

1. An initial inventory of emissions broken down by source sectors or categories. For BCAT purposes, the BFS uses the 1995 PM10 MAG State Implementation Plan Inventory as a starting point. This breakdown is used to isolate the effects of specific control measures on specific source sectors, that is, a group of sources with similar emitting characteristics. Sources are grouped in sectors to make sure that sufficient detail exists to identify “like” sources that could have “like” controls applied,
2. Econometric forecasts of growth, which are used to project the change in overall demand for goods and services and other emission related activities for each source sector over time, and
3. Retirement rate assumptions to take into consideration the retirement of existing sources (those in the base 1995 inventory) that reach the end of their useful life, or reach a point of competitive obsolescence.

The BCAT separates the analysis between existing (those in existence in the base 1995 emission inventory) and new (post-1995) sources within each source sector. The effective utilization of each is dependent on the remaining (non-retired) capacity or activity of existing sources compared to the overall demand or growth rate. The effective utilization of new sources is the difference between the un-retired existing sources and the overall demand expressed by the growth factor. The BCAT recognizes that the control efficiencies of new sources may be different than the older existing sources. The differentiation of the control levels between existing and new sources can have a significant impact on the projected future emissions. In summary, an analysis considering these factors leads to a projection of the emissions of the pollutants affecting visibility over the next twenty years.

Visibility is dependent on the concentration, size, and composition of particles in the air and the concentration of certain gases in the atmosphere. The ability of each type of particle and gas to interfere with visibility is well known and is characterized by a quantitative factor referred to as the light extinction efficiency of the particle or gas. Air quality models are used to convert the emissions of pollutants into concentration estimates of these visibility impairing particles and gases. These air quality models range from simple speciated-rollback models, where there is an assumed linkage with the emissions and the concentration of particulate matter and gases in the atmosphere, to extremely sophisticated “first-principles” models that solve a set of partial differential equations over a 3-dimensional grid space to simulate the atmospheric transport, deposition, dispersion, and chemical conversion processes in the atmosphere.

In any case, the projection of emissions is the first step in the process of understanding the impact on visibility. These emissions are then converted to estimates of particulate matter and gases of interest through “transfer coefficients” that convert emissions in metric tons per day into concentrations of the pollutants in the atmosphere in micrograms per cubic meter of air. (The transfer coefficients used in BCAT can be derived from either simple roll-back models or developed from more complex air pollution models and computing the ratio of concentration changes to emission changes). These concentration estimates are then converted to visibility impairment (or light extinction) through the application of light extinction efficiencies.

The Summit established certain criteria for the analytical tool, BCAT. The analytical tool was developed to generate estimates of the visibility changes that could occur from a control option scenario for the average of the worst 20% of the winter days, when the brown cloud is most pronounced, and the annual average day. Emission and visibility projections are performed for the years 1995, the base inventory year, 2003, 2006, 2010, 2015, and 2020. The BCAT generates four potential outcomes (the winter worst 20% and annual average day for the Baseline Forecast Scenario and the control option scenario) for each of the years identified. These outcomes allow comparison of the control option scenario with the Baseline Forecast Scenario and, more importantly, the projected outcomes allow comparison of one control option scenario with another.

### **1.3 Defining a Control Option Scenario**

A control option scenario is an optional program or control measure intended to reduce the emission of air pollutants. It is intended to change the projection of future emissions from what otherwise would have been projected under the Baseline Forecast Scenario. A control option scenario has two fundamental characteristics:

1. It has an action, plan, or requirement that could change the emissions in the atmosphere and thus affect visibility, and
2. It has an associated cost.

The BCAT is designed to produce quantitative estimates of the effectiveness of control option scenarios. Please note: control option scenarios must have a quantifiable estimate of emission change in order for the assessment to occur. When emission changes cannot be quantified or defined, or in cases where cost associated with the control option scenario cannot be characterized, the assessment tool will not provide a useful foundation for decision-making.

Section 2 of this document explains in detail how to describe a scenario, organize the data necessary to define the scenario to the BCAT, utilize the assessment tool to determine the effects of the scenario on visibility, and produce a quantitative estimate of the cost-effectiveness of the control strategy. Sections 1.5 and 1.6 provide an explanation of how to interpret the results of the assessment of a control option scenario.

What is a control option scenario? A control option scenario is a hypothetical characterization of a control measure or program that could be instituted and is not

included in the Baseline Forecast Scenario. For instance, the requirement for some new dust control measure, which does not currently exist in the requirements under federal, state, or local regulations, is a candidate for examination as a control option scenario.

Examples of control option scenarios include: a program requiring improved dust control measures, the acceleration of the implementation of an existing federal or state requirement, a change in the requirements for new sources for additional control measures resulting in higher levels of pollution capture or reduced emission levels, acceleration of the retirement of older higher emitting vehicles, or new requirements to retrofit existing facilities or equipment to utilize better pollution control equipment.

As stated above, in order for a control option scenario to be assessed, there are two pieces of information required. The first is a quantitative estimate of the change in emissions that would occur for each affected source sector. The second is the cost of the control measure for each affected source sector. The characterization of the emission change can be done in a number of different ways within the architecture of the BCAT. The financial information related to changes in annual operating expenditures and in the cost associated with capital expenditures is also necessary to perform in assessment. The final result of the assessment is a characterization of the control measure in terms of the unit of visibility improvement that can be achieved from the control measure and the cost-effectiveness of the control measure expressed in the levelized annual cost per degree of visibility improvement.

In order to combine the effects of one-time costs, such as capital improvements, with annualized cost associated with property maintenance, a process is used to convert the one-time capital costs into a levelized annual cost. This is discussed more fully in section 2.3.7.

## **1.4 Basic Computational Approach**

The BCAT performs parallel sets of calculations within its computational framework. These calculations include the emission and visibility projections for the Baseline Forecast Scenario for the average of the winter 20 percent worst days and the annual average day, along with parallel calculations for these periods for the control option scenario.

All the calculations begin with an examination of the projected growth in emission related activities for each source sector and the retirement of existing sources in that source sector. As the older sources (in existence in 1995) retire, there will be a reduction in the ability of these existing sources to satisfy the demand for goods and services (or vehicle miles traveled); this demand must be satisfied by new sources in order to satisfy overall demand within the area. The next step in the calculations is to estimate the effective utilization (which relates to the emission generating activities) for the existing sources as of the baseline reference date, which in this case is 1995. The second examination is to estimate the amount of output for emission related activity associated with new sources in order to satisfy the overall demand. This separation

between existing sources and new sources allows the examination of the differences between control levels for the older existing sources and new source population for the source sector.

The 1995 base emission inventory is used as a reference, or starting point, for forecasting. For the purpose of the BCAT, it is assumed that the control efficiencies used in the system are all stated relative to the control efficiencies of sources in 1995. Initial projections have been performed for the existing source population and the new source population independently, based on the effective utilization of the source category and the source type. The relative control efficiency of the source category is compared to the 1995 control levels. These two independent emission forecasts are then combined to perform the overall forecast of emissions over the time horizon of the analysis (i.e. 1995 through 2020).

The initial emissions forecasts are based on the traditional pollutant species of interest and the inventories for the particulate matter state implementation plan. However, the composition of the finer particles is important in characterizing visibility. Therefore, source-sector-specific speciation ratios are used to convert the fine particulate matter inventory (i.e. particles < 2.5 microns) into the fractions of interest to visibility assessment work (i.e. organic carbon particles, elemental carbon particles, and other fine materials or soils). This speciated emission inventory is used as the basis for projecting air quality concentrations in the atmosphere.

The concentration of particles in the atmosphere can be measured through a variety of standard methods, primarily through the collection of a large volume of air through a filter with a subsequent examination of the composition of the material collected on the filter. During the 1994 to 1996 timeframe an intensive measurement program was carried out to gain information about the characteristics of the brown cloud problem in Phoenix, Arizona. Extensive particle filter measurements and direct measurements of visibility at multiple sites in Phoenix were collected and correlated for this study period. These results and data from these previous studies provided a substantial part of the air quality technical foundation for the BCAT.

The rate at which light is absorbed or scattered, contributing to visibility impairment, is directly related to the concentration of particulate matter and certain gases in the atmosphere. Once the speciated emission inventory is calculated it is converted into an estimate of the concentration of particulate matter and visibility obscuring gases in the atmosphere. This is done through a simple speciated-rollback air quality model. In this model, it is assumed there is a linkage between emissions within the area and the concentrations that have been measured. The BCAT has been constructed in such a way that results from more sophisticated modeling analyses done in the future could be substituted for this simplified speciated-rollback modeling analysis.

Once the projected aerosol concentrations have been developed, they are converted to an estimate of the light extinction caused by the various types of particulate

matter and gases in the atmosphere. This is done through particle/gas specific light extinction efficiency factors. The extinction efficiency factors used in the BCAT are those from the Interagency Monitoring of Protected Visual Environments (IMPROVE) program. IMPROVE, which consists of all key federal agencies involved in visibility protection of the national parks and wilderness areas, was formed in March 1988 to characterize background conditions, determine current visibility impairing sources of pollution, collect data on the current and historical conditions, and to promote development of improved monitoring techniques. In addition to the IMPROVE extinction efficiency model, the BCAT also includes an ability to switch to an extinction efficiency model derived from an extensive field study performed in the Phoenix area in the 1994 to 1996 timeframe. In order to have a consistent framework for policy decision-making, the Summit made the policy decision to adopt the IMPROVE model for its assessment work.

The last of the detailed parallel calculations is the calculation of the total light extinction by pollutant species, source sector, forecast year, and study period (winter/annual) for the Baseline Forecast Scenario and the control option scenario. The next step is the comparison of the control option scenario with the Baseline Forecast Scenario. The summary report contains projections of the overall light extinction for the Baseline Forecast Scenario and control option scenario for both study periods (the winter worst 20 percent days and the annual average day). The change in light extinction is then reported in a variety of ways. This includes a change in light extinction, a change in the standard visual range, and a change in the haziness index or deciview, which is a perceptibility scale associated with visibility. This final metric is utilized to calculate cost-effectiveness. In addition, the report summarizes the projected changes in emissions, stated both in terms of the basic emission inventory and the speciated emission inventory.

The overall annualized costs for operating and maintenance are combined with a levelized capital cost in order to yield a levelized annual total cost for the control strategy. This levelized cost is then divided by the degree of visibility improvement expressed in haziness index units (or deciviews) to yield a cost-effectiveness factor for the control option scenario.

## **1.5 Control Option Scenario Assessment Report**

The control option scenario assessment report is a two-page summary of the results of a control option scenario evaluation. This is the first worksheet, or Tab, in the workbook and is labeled “1.5” corresponding with this section number in the documentation.

The first page reports the results of the analysis for the worst 20% average winter day; the second page reports the results for the annual average day. The report layout and content is the same for both pages. The following is a summary of the calculation results included in the reports.

The control option scenario title and a short description are located at the top of the page. Footnotes that provide additional clarifications and qualifications of the analysis are at the bottom of the report. Under the short description is a banner line indicating whether the results on the page are for the worst 20% average winter day or the annual average day. Below this banner are the analysis results.

The first table under the banner shows the visibility metrics for the control option scenario. The next table is identical in format and shows the same metrics for the Baseline Forecast Scenario. The top of the table includes three lines that show the contribution to light extinction from emissions in the control region, the contribution to light extinction from background sources outside the control region, and the contribution to light extinction from Rayleigh scattering (i.e. from clean air molecules in the atmosphere). The sum of these three contributions to light extinction represents the total light extinction and is expressed in inverse Megameters (1/Mm). A large number (over 100) for light extinction represents significant visibility impairment while a small number (less than 20) represents very little visibility impairment. Visibility impairment is also reported in two other metrics that are derived from the total light extinction. The first is the standard visual range (i.e. how far one can see an object) expressed in kilometers. The last metric is the haziness index expressed in deciviews. This metric relates to “perceptible” changes in visibility to the human eye, and is similar to the decibel scale for sound. Generally, a change of 1.0 deciviews is considered barely perceptible.

The next set of tables show the change between the control option scenario and the Baseline Forecast Scenario. First, the change in the base emission inventory pollutants (in metric tons per day) is shown by pollutant for each of the six analysis years. Next, the change in the speciated emission inventory (i.e. the inventory which breaks down the emission of fine particulate matter into its component parts) is shown for each pollutant species and year. The next table shows the change in the key measures of visibility impairment, i.e., light extinction in inverse mega-meters, standard visual range in kilometers, and haziness index in deciviews.

The last table shows the projected cost of the control option scenario for capital expenditures and annual operating and maintenance cost. The capital cost is converted to a levelized annual contribution and added to the annual operating and maintenance cost to generate the levelized annual total cost which is expressed in millions of dollars per year over the life of the control measure. The cost benefit is then computed by dividing the levelized annual total cost by the change in haziness. This final value is computed by year and expressed in millions of dollars per year per deciview of change. The value for the last analysis year, 2020, is the most appropriate for comparing two or more control option scenarios. More details about some of the calculation methods used in the control option scenario assessment report can be found in section 2.1 of this document.

## **1.6 Interpretation of Results**

It is important to understand that the two key results of assessments with the BCAT (visibility change and cost effectiveness of the control option scenario) are

directionally correct, but the absolute values associated with the visibility changes or cost-effectiveness are only as accurate as the physics characterizing emission changes in the atmosphere and its effects on visibility, and the underlying data relied upon in the modeling. Utilizing the cost-effectiveness index to compare control option scenarios is the most appropriate way to interpret the results. To assume that a particular control measure will result in an absolute value of change in visibility without performing more rigorous atmospheric modeling would be shortsighted. However, since the purpose of BCAT is to examine and prioritize the various control option scenarios developed by the Summit, its use in examining the relative cost effectiveness of the options is appropriate.

Because each control option scenario is compared against the Baseline Forecast Scenario as a "deviation" from the baseline, all of the relative values associated with these changes are correct and comparable. However, if one were to combine the emission control effects of several of the scenarios together, a larger deciview change would occur than the simple arithmetic sum of the individual results of the individual control option scenario assessments. This is due to the fact that, as the air becomes cleaner, smaller changes in the concentration of particulates will result in a more perceptible change to the human eye. This phenomenon is not true for the computed improvement in light extinction. Light extinction is linearly related to the aerosol concentrations in the atmosphere. When attempting to combine the effects of multiple scenarios together it is important to add the cumulative effects of the change in light extinction together and then convert that measure into an appropriate haziness index. In cases when scenarios with very small changes in visibility are combined, it may appear that the deciviews are additive and linear, but over larger changes they will not be.

That being said, it is important to recognize that some combinations of control strategies can not be reflected as a simple sum of the basic individual scenarios. This is especially true for overlapping controls at a given facility or sector that are mutually exclusive (i.e., if you plug A into the wall plug, you can not plug B into the same plug.). An example of this would be if two stationary source control measures applied to the same sources. One of them requires a technology achieving a 90% reduction in emissions through the application of technology A. But if technology A is put on, technology B could not be applied. In this case the user should only consider the cost and benefits of technology A.

Also, when examining the cost associated with future projected control measures it is important to understand that the technology associated with pollution control continues to evolve over time. All costs associated with the assessment are stated in year 2000 dollars. However, a control measure that is not instituted until 2010 may actually cost less in 2000 dollars because of improvements in technologies.

Thus, policymakers are cautioned not to infer more than is appropriate when examining the results of the BCAT. To summarize, the BCAT is a directionally consistent framework for assessing changes from a Baseline Forecast Scenario associated with control option scenarios in a relative sense. Assuming that the model will predict

the exact value of future visibility conditions would be a mistake given the uncertainties associated with economic forecasts, population projections, changes in the emission characteristics of sources, and air quality modeling. For ranking a variety of control option scenarios to identify those that have a higher degree of cost-effectiveness, BCAT is an appropriate tool.



## **2.0 Using the Assessment Tool**

Section 2 describes how to use the BCAT to assess control option scenarios. It is intended for the technical policy analyst, familiar with Microsoft Excel, who will be performing assessments.

In this section we discuss:

- The details of the calculation in the summary report,
- The sources of information (the other worksheets or “tabs”) that feed into the summary report,
- How to organize the data for an assessment, and, finally,
- How to enter the control option scenario into the BCAT and perform the analysis.

### **2.1 Summary Report Content and Interpretation**

In this section we describe the calculation methodology used in developing the information for the two-page Control Scenario Assessment Report (Tab 1.5) for the control option scenario and the sources of information for the calculations. The sources of information are the other Excel worksheets (or “Tabs”) that are referenced by the Control Scenario Assessment Report. Guidance on organizing and entering data into the BCAT, and specialized analysis methods are then explained in the remainder of Section 2.

#### **2.1.1 Control Option Scenario Description**

The Control Scenario Assessment Report contains information for the Worst 20% Average Winter Day on page 1, and information for the Annual Average Day on page 2. The information describing the control option scenario includes a short one-line title for the scenario, a four-line description of the scenario, and up to 10 lines of footnote information to clarify assumptions made in the assessment located below the report tables.

The control option scenario title entered at the top of Tab 1.5 is reflected on the top off all worksheets that may have content changes dependant on the control scenario data. The description and footnotes entered at the top of Tab 1.5 are also reflected on the bottom half (annual report) to eliminate duplication of entry. The data entry process for these fields is described below in Section 2.3.

#### **2.1.2 Visibility Projections for the BFS and Control Option Scenarios**

The light extinction values projected from the sources involved in the modeling exercise are totaled and reported in the first line of the light extinction summary tables located at the top of both pages of the Control Scenario Assessment Report (Tab 1.5). These cells refer to the values in the total columns (AR-AW) of Tabs 4.1.8 and 4.2.8 for the Baseline Forecast Scenario and the control option scenario, respectively.

In addition to the light extinction contribution from the source sector cells modeled in the assessment, the light extinction associated with the background concentrations of particles and gases, that is, those that originate outside of the modeling region, must also be taken into consideration. The background concentration assumptions from Tab 3.10 (D19-K19) are converted into light extinction for the 1995 BFS Table in cell E25. Since the assumption is made that no change in background will occur, the background values for all other years, and for the control scenario refer to this calculation in cell E25.

In addition to background, the contribution to light extinction from Rayleigh scattering, that is, the light lost by simply traveling through perfectly clean air must be added. This is shown as the third line. For the Phoenix area, a value of 13 is used. The sum of these three components represents the total light extinction coefficient of the atmosphere.

Light extinction values in these tables, and throughout the BCAT, are expressed in inverse Megameters (a value divided by one million meters). The next line of the visibility report converts the light extinction into standard visual range expressed in kilometers, where:

$$\text{STANDARD VISUAL RANGE} = 3.912 / (0.001 * \text{LIGHT EXTINCTION})$$

The subsequent line converts the light extinction into the haziness index or “deciviews” of visibility impairment, where:

$$\text{DECIVIEWS} = 10 * \text{NATURAL\_LOG} (\text{LIGHT EXTINCTION} / 10).$$

The change between the Baseline Forecast Scenario and the control option scenario expressed in this last metric, deciviews, is the visibility metric used to compute the final cost effectiveness for the control scenario. Haziness (in deciviews) was chosen as the metric for cost effectiveness since a 1 deciview change represents a barely perceptible change in the visibility for any starting reference value of deciview, whereas, the other visibility metrics are not linearly related to “perceptible” changes.

### **2.1.3 Projected Changes in Emissions**

After the light extinction values are computed, the projected changes in the emissions between the control option scenario and the Baseline Forecast Scenario are reported. Note that a negative value in the emission change report represents a decrease in emissions in the control option scenario compared to the BFS.

The first emission report shows the differences in the projected emissions (in metric tons/day) for the pollutants contained in the MAG Inventory. These values are generated by subtracting the corresponding cells from the BFS Projected Emissions (Tab 4.1.5) from the corresponding cells from the Control Option Scenario Projected Emissions (TAB 4.2.5). In these reference Tabs, the Worst 20% Average Winter Day total values are in Row 80. The Annual Average Day total values are in Row 156.

The second emission report shows the differences in the projected emissions (in metric tons/day) for the pollutants contained in the speciated emission inventory used for the visibility analysis. In the speciated emission inventory the PM<sub>2.5</sub> in the MAG Inventory is broken down into its key constituent parts: organic carbon, elemental carbon, and other fine materials (dusts and soils). The change in speciated emissions is determined by subtracting the BFS speciated emissions (Tab 4.1.6) from the control option scenario speciated emissions (Tab 4.2.6). Again in these reference Tabs, as in most Tabs, the Worst 20% Average Winter Day total values are in Row 80, while the Annual Average Day total values are in Row 156.

#### **2.1.4 Projected Changes in Visual Air Quality**

After the projected changes in emissions are reported, the projected changes in the visual air quality metrics are reported. The visual air quality metrics are those referred to above: light extinction, standard visual range, and haziness. These values are computed by subtracting the BFS metrics from the control option scenario metrics at the top of the page. Note that a negative value for change in light extinction and haziness (deciviews) represents an improvement in air quality under the control option scenario. For standard visual range, a positive value represents an improvement.

#### **2.1.5 Projected Costs (Capital, O&M, Annualized)**

After the change in visibility is reported, the control costs are reported. The control costs include the total capital expenditures in millions of dollars for each year of the analysis period and the annual operating and maintenance cost per year during the analysis period. Note that capital cost is reported as the total capital during the investment period, not only in those analysis years, and not on an “annual” basis. For example the value reported for capital cost in 2003 would include the capital costs for 2003, 2004, and 2005, with the next analysis period starting in 2006. The values in this table refer to the corresponding cells in the Financial Analysis worksheet (Tab 3.2) in lines 31 and 32 for capital and operating costs, respectively.

The levelized annual total cost in millions of dollars per year is from line 39 in Tab 3.2, which reflects the total of the annualized average of the operating costs over the investment period, and the levelized annual capital cost. The financial factors and methods are discussed more fully in Section 3.2 of this document.

#### **2.1.6 Cost Effectiveness (\$/deciview change)**

The Cost Effectiveness or Cost Benefit is computed by dividing the levelized annual total cost by the change in haziness (in deciviews) reported above. The Cost Effectiveness is reported for each period in the analysis, although the value of most interest is the final value in 2020.

Cases may exist where the control option scenario generates little improvement compared to the BFS in 2020 but a larger improvement in an earlier year. In these cases it would be more appropriate to compare control option scenarios on the basis of an

average cost effectiveness (i.e., averaging the cost effectiveness over the time periods of the analysis and using this averaged value). In such a calculation the cost effectiveness of the scenario would be more consistent with one from a scenario where the final 2020 value is the maximum for the analysis period.

## **2.2 Organizing Data for a Control Option Scenario**

As was discussed in Section 1, the data for sources is organized into categories or source sectors. For each analysis year, the emissions can be altered for any or all of the pollutants generated by the source sector. Because of this flexibility, data is best organized around this source sector cellularization.

The first step in the assessment of a control option scenario is the formulation or conceptualization of how the scenario will change emissions of pollutants to the atmosphere over time. The next step is determining the best method of characterizing the emission change. The final step is to project the costs associated with the scenario.

Many factors must be considered in characterizing and defining a control option scenario. The simplest approach is to focus the analysis on a particular source sector. Organizing the control option scenario by source sector makes it easier to characterize the emission change and the costs, even in cases where multiple source sectors are being considered together. An input data worksheet and master source sector reference list are included as Tabs 2.2.1 and 2.2.2, respectively, as discussed in detail below. They can be printed out and filled in by hand to keep notes and references together until the information is actually entered into the BCAT.

### **2.2.1 Source Sector Input Data Worksheet**

To aid in the organization of data for assessment, a Source Sector Input Data worksheet was developed and is included as Tab 2.2.1. This worksheet should be printed out for manual organization of data as it is collected prior to entering the data into BCAT. This worksheet contains areas for all of the input data necessary to define a control option scenario for a particular source sector. References are provided in each data area that corresponds to the Tab in the workbook that is used for entry of the data. The Tab references also link back to the section numbers in this document where more information can be found about developing and using the data.

The top of the form is used to collect the scenario title and description that will be entered and appear at the top of the Control Scenario Assessment Report (Tab 1.5). In addition, it contains a line that should be filled in with the line number reference and title of the source sector affected. This line number reference and title should be taken from the source sector list in Tab 2.2.2 described in the next section.

Various methods can be used to characterize the emission changes for a scenario. The worksheet provides the ability to collect data on any of these common methods. These are changes from the Baseline Forecast Scenario and include:

1. Adjusting the growth rate assumption for the source sector,
2. Adjusting the retirement rate assumption for the source sector,
3. Adjusting the control efficiencies by pollutant for existing sources,
4. Adjusting the control efficiencies by pollutant for new sources, or
5. Directly entering the change in metric tons per day by pollutant.

These methods, their advantages, and their disadvantages are discussed in Section 2.3, below.

The form also includes spaces to enter the capital equipment costs and annual operating and maintenance costs. These costs should be entered in year 2000 dollars as discussed below in Section 2.3.7.

Finally, the form contains space for footnotes, assumptions, the identity of the individual who prepared the data and a date. The source sector input reference list can be printed on the back of the input data form for convenient reference. It should be noted that the factors entered are applied to both the winter and annual average calculations.

### **2.2.2 Source Sector Data Entry Control List**

The source sector data entry control list contains the names of the source sectors and the “data” line number in the source sector input worksheets. Note that summary source sectors are included that do not have line numbers. An analysis should not be attempted using these lines, which are identified by the lack of a Data Line Number, since the BCAT performs all calculations at the detail level. An experienced analyst might be able to bypass this limitation, but care should be made that all necessary calculations were properly executed.

The Data Line Number/Sector Name provides a cross check during data entry to make sure that the data from the input form is being entered onto the correct line in the BCAT control option scenario data entry worksheets.

## **2.3 Entering Control Option Scenario Data Into the BCAT**

Once the data for the control option scenario is organized, it needs to be entered into the appropriate control option scenario input data worksheets. Because the worksheets are large and complex, data input should be slow and methodical to insure accurate results.

Section 2.3.1 will provide some suggestions on techniques that can help improve data input efficiency and accuracy. As noted above, there are a variety of ways to enter the effect of the control option scenario on emissions. These are discussed in Sections 2.3.3 through 2.3.6. The entry of cost information and special considerations for setting up cost data is discussed in Section 2.3.7. Finally, Section 2.3.8 provides instructions for printing the report and some audit steps that can be useful to assure that the data entry was performed correctly.

### **2.3.1 Process and Tips for Entering Control Option Scenarios**

We strongly recommend that data be entered in the order it appears on the data input worksheet and that data entry be done following the same process each time the BCAT is used. As data is entered, a small check mark should be placed next to the lines that have been successfully updated. In this way, if there is an interruption in the data entry process, it will be easy to verify what data has been entered.

It is important to make certain that all entries are on the desired row, particularly when entering data in the larger data entry sheets that have rows corresponding to the source sectors. A suggestion for making this task easier is to highlight the row number that data input will be performed in. Highlight it by changing its color to bright green or light gray. The color distinction will help ensure when scrolling across large sheets that the correct row is receiving the input data. Added color will also make it easier to audit the data entry, since the line will stand out from all the other lines in the worksheet.

When entering control efficiency adjustments or emission inventory adjustments, both of which are organized by pollutant, the adjacent columns in the BCAT correspond to the same order as the pollutant list. Thus, the first set of columns in the efficiency worksheet correspond to PM-10, the next columns correspond to PM-2.5, etc. The columns associated with a particular pollutant have a unique color code to help denote the boundaries between pollutants. These color-coded highlights correspond to the colors used on the data input preparation worksheet (Tab 2.2.1).

### **2.3.2 Control Option Scenario Title and Description**

The first step in data entry is to open the master BCAT.xls file, and save it under a different name corresponding to the title of the control option scenario. **ALWAYS MAKE THIS SAVING PROCESS UNDER A DIFFERENT NAME THE FIRST STEP IN YOUR INPUT PROCESS.**

Choose a name that is a suitable short form for the scenario title and perform a “File/Save As” to that new name. Failure to do so may result in “saving” a partially updated file back to the BCAT.xls master file, resulting in problems for the next scenario since some of the control fields will not be set to the default values.

AFTER the file has been saved under a different name, select Tab 1.5, position the cursor on cell C1, and enter the control option scenario title from the top of the data input worksheet. Then enter the short description in cells B3 to B6. If not all the lines are used enter a blank (an apostrophe followed by a space) to eliminate the text in the remaining lines. Then enter any footnote information in cells C62 to C71, again entering a blank in any unused lines.

CHECK to make sure that the title and descriptions entered above appear in the corresponding cells for the Annual Average report in Rows 72 to 142. If they do not appear correctly, change the cell equations to refer to the above data entry cells.

SAVE the control option scenario workbook so the data just entered is not lost and continue with data entry below.

### **2.3.3 Control Option Scenario Growth/Retirement Rate Adjustments**

The Baseline Forecast Scenario includes a projected growth in emission-related activities from the base year 1995 to each of the forecast years. These are defined by source sector. The projected growth is reflected as a cumulative growth factor. The growth factors are normalized so that the growth factor for 1995 is equal to 1.0. For example, if one were to assume that the growth in emission related activities for a source sector increased 100% over the 1995 level, meaning that it doubled, the growth factor would be equal to 2.0

In defining a control option scenario, one may examine alternative strategy components that could alter the projected growth rate by changing demand for goods and services or industrial activity. Limiting growth of a source sector can be simulated in the BCAT by changing the Growth Rate Adjustment Table in Tab 2.3.3. The value entered into the adjustment table is multiplied by the baseline growth rate factor to yield an adjusted growth rate. The user of the system should refer to the baseline growth factors described in Section 3.7 and contained in Tab 3.7 for more complete information. As an example, if the original BFS growth rate was 1.6 (representing a 60% increase from 1995) and the desired growth rate would be only half of that (representing a 30% increase from 1995), the growth rate adjustment factor entered into Tab 2.3.3 would be 0.8125 ( $1.3/1.6$ ). If it were desirable to cut the activity level for the sources below the 1995 levels, say to 80% of the 1995 levels, the growth rate would be entered as 0.5 ( $0.8/1.6$ ) in this same case. This type of characterization is most appropriate when all of the pollutants from the source sector are going to be affected proportionately. If a control strategy will only impact some of the pollutants, adjusting control efficiencies or entering inventory adjustments, as discussed below, would be more appropriate.

The Baseline Forecast Scenario also includes, for each source sector, a projected retirement fraction of the sources that were in existence in 1995 for each forecast year. This value is a cumulative effect. In 1995, the value is 0.0. When all of the existing sources are retired, the retirement value is 1.0.

In defining a control option scenario, one may examine alternative strategy components that could “accelerate” the projected retirement of older, higher emitting sources through restrictions or incentives. Since the overall output of the non-retired existing and new sources is equal to the overall growth rate, adjusting the retirement rate can have a significant effect on emissions if there is a significant difference between the control efficiency of existing (1995) and new (post 1995) sources.

Accelerating retirement of a source sector can be simulated in the BCAT by changing the Retirement Rate Adjustment Table in Tab 2.3.3. The value entered into the adjustment table is multiplied by the baseline retirement rate in Tab 3.8 to yield an adjustment retirement rate for the scenario. If the product of the adjustment factor and

the baseline retirement rate exceeds 1.0 (100% retirement) then it is limited to 1.0 when used in the determination of overall utilization of new and existing sources located in Tab 4.2.1. Again, this type of characterization is most appropriate when all of the pollutants from the source sector are going to be affected proportionately. If a control strategy will only impact some of the pollutants, adjusting control efficiencies or entering inventory adjustments as discussed below would be more appropriate.

#### **2.3.4 Control Option Scenario Existing Source Control Efficiency Adj.**

There may be control option scenarios that are designed to require higher levels of control efficiencies for existing (1995) sources. This would be characterized as a retrofit requirement for these older sources. This retrofit could affect only certain pollutants, or may affect one pollutant differently than another. For this reason, the Existing Source Control Efficiency Adjustment is defined by source sector, year and pollutant.

The BFS existing source control efficiencies by source sector and pollutant are defined in Tab 3.9.1. The Existing Source Control Efficiency Adjustments in Tab 2.3.4 are multiplied by the baseline values in Tab 3.9.1 to yield the effective control efficiency for the control option scenario. These results are located in Tab 4.2.2-ExEff.

PM-10 is a measure of all the particulates in emissions or the atmosphere that are smaller than 10 microns in aerodynamic diameter. PM-2.5 is a measure of the particles less than 2.5 microns in aerodynamic diameter. Therefore, PM-10 includes PM-2.5, and the difference is referred to as Coarse Material, which is modeled differently for visibility related purposes than the PM-2.5 material. When entering control efficiency adjustments for PM-2.5, it is important to remember that PM-10 includes PM-2.5. If the user were to enter an increase in the control efficiency for PM-2.5 without some corresponding adjustment for PM-10 that includes PM-2.5, the resulting control scenario will “project” an increase in the Coarse Material fraction of PM-10. (Referring to the Audit Tab 4.4 columns X to AC rows 15 and 16 can alert the user to such a problem. If the projected emissions from the control scenario on line 16 is larger than the baseline on line 15, then there is an inconsistency in the control efficiency adjustments entered for the scenario).

If a control scenario only directly affects the emission of PM-2.5 and is known, the adjustment to PM-10 can be estimated by examining the change in the PM-2.5 control efficiency and the ratio of PM-2.5 to PM-10 for the source sector. For instance, if there were a 50% reduction in PM-2.5 for a source with 30% of PM-10 being in PM-2.5, there would be a 15% reduction in the overall PM-10 emission rate. This issue applies to existing source control efficiencies, as well as the new source control efficiencies discussed in the next section.

#### **2.3.5 Control Option Scenario New Source Control Efficiency Adj.**

There may be control option scenarios that are designed to require higher levels of control efficiencies for new (post 1995) sources. This requirement could be characterized as a change in the new source performance standards, best available control technology, or lowest achievable emission rate for the source sector, or simply a new requirement that

is not in the BFS. This more restrictive standard could affect only certain pollutants, or it may affect one pollutant differently than another. For this reason, the New Source Control Efficiency Adjustment is defined by source sector, year and pollutant.

The BFS new source control efficiencies by source sector and pollutant are defined in Tab 3.9.2. The New Source Control Efficiency Adjustments in Tab 2.3.5 are multiplied by the baseline values in Tab 3.9.2 to yield the effective new source control efficiency for the control option scenario. These results are located in Tab 4.2.2-NwEff.

### **2.3.6 Control Option Scenario Emission Forecast Adjustment**

The final method available to characterize the change in the emissions associated with the control option scenario is to enter the change by pollutant and year in metric tons per day in Tab 2.3.6. Note that emission reductions are entered as NEGATIVE values. This option is most appropriate when very complex strategies, requiring sophisticated models beyond the scope of the BCAT are needed to characterize the changes. An example could be changes in mobile source emissions that require the use of a standard mobile model, or assessing the effect of a market or incentive based program where complex external analyses are required to determine the change in emissions. The projected emissions for the control option scenario are derived in parallel with the computations for the baseline, and the values entered in Tab 2.3.6 are used to adjust the projected emissions to the final control option scenario forecast. These results are located in Tabs 4.2.3 and 4.2.4.

### **2.3.7 Control Option Scenario Capital and Operating Costs**

The control option scenario estimated costs for capital equipment and for annual operating and maintenance costs are entered into the scenario cost worksheet (Tab 2.3.7). All costs entered must be for the same basis year for all control option scenarios. The basis year for use of the BCAT for the Governor's Brown Cloud Summit assessments are year 2000 dollars.

Capital expenditures or costs are generally one time costs associated with fixed equipment with a useful life of several years. When entering capital costs, make sure that the total capital cost for the analysis period is properly reflected, not just the reporting year. For example, the entry in "2003" should include not only the capital costs in 2003, but also for 2004 and 2005, since the next analysis period begins in 2006.

Annual operating and maintenance costs are averaged over an assumed 20-year life. This averaging allows for situations where the annual cost changes over time. This could occur if a program were phased in over time, or if the number of sources in the program changes over time.

### **2.3.8 Printing Results and Auditing**

After all of the data have been entered, it is recommended that the data entry be verified for accuracy. Each sheet that was altered should be reviewed and the values in the worksheets compared to the values on the data input worksheet. These should be

checked off as they are verified. After the data entry has been verified, the assessment report (Tab 1.5) should be reviewed for reasonableness. If the scenario is expected to reduce emissions of some pollutants, the emission change tables should be reviewed to ensure that the pollutants of interest are showing a decrease in emissions, and that those pollutants for which changes are not anticipated are showing no change from the BFS.

After the worksheet is audited, it should be saved and then Tab 1.5 printed out. If necessary the user should view the headers and footers for the report and adjust them accordingly. The assessment report prints on two pages. The first page is the report for the Worst 20% Average Winter Day. The second page is the report for the Annual Average Day.

## **2.4 Assessing Multiple Sector or Combined Scenarios**

There are often times when it is desirable to determine the impact of several individual control option scenarios collectively. This can be done with three different methods depending on the available data and desired result.

First, if the combination has only one control action for each source sector (i.e. each source sector assessment is different) then all of the raw data input for each of the individual assessments, including control actions and costs, can be input into the BCAT for a single integrated run. If the combination has more than one control action that would alter the emissions for the same source sector, then this method should be avoided.

A second approach is to identify the emission changes by source sector and the costs and total them up. The breakdown of sector specific emission changes is reported in Tab 4.2.9. The sector lines can be copied out and pasted as values into Tab 2.3.6 (Direct Emission Control Change Input Option) on the corresponding line for the sector. If more than one control option scenario impacts the same source sector, these changes should be totaled before being entered into Tab 2.3.6. The projected costs are then copied from the individual control option scenario into the cost Tab (2.3.7) for the integrated scenario. Again, if there are multiple scenarios that affect the same source sector, the costs should be totaled before entering them into the cost Tab.

The third and most simple approach would be to build a separate spreadsheet that includes the projected change in light extinction, and projected levelized annual cost. The BFS total light extinction is the starting point for the change analysis. The sum of the individual light extinction contributions is added. This sum is then converted into deciviews using the equation in Section 2.1.2 above. Finally, the total levelized cost is computed, and divided by the deciview change to yield the cost effectiveness.

## **2.5 Comparing and Ranking Scenarios**

When comparing scenarios, it is useful to build a separate worksheet that contains the key analysis results. A table with the scenario title, and 2020 cost effectiveness can be

sorted to yield a ranked list of the options. Other information of interest can be included in the table to provide for other analyses.



### **3.0 Key Baseline Input Data and Control Tables**

The BCAT was designed with flexibility in mind. Most of the key input assumptions and control information could be easily modified to allow investigation of other issues. For instance, most of the labels used to define rows and columns in the worksheets all refer back to a single sheet. This allows a change in one place to change all the related sheets in the BCAT. In addition, key input tables are linked to the computational logic from fixed locations. This linkage allows the underlying data to be modified easily if newer, higher quality data becomes available.

This section of the report describes the key input data in the BCAT that controls the calculations and report generation. It is intended for the technical policy analyst who will be using the BCAT to assess control option scenarios.

#### **3.1 Analysis Years and Seasonal Considerations**

Many assumptions were made in order to develop the BCAT. The Governor's Brown Cloud Summit initially needed to decide which years to include in the projection of emissions and visibility conditions. After reviewing available data and forecasts, the decision was made to base the analysis on six years. These years include 1995, the year of the base inventory used to develop projections, and 5 forecast periods: 2003, 2006, 2010, 2015, and 2020. These years are loaded into the table at the top of Tab 3.1 in cells C8 through H8. All other tables in the BCAT that contain year labels refer to these entries. If a future analysis using a different set of analysis years should be desired, these entries in Tab 3.1 could be modified. All of the subsequent worksheets and reports would reflect these new labels.

The Summit also decided to perform the analyses based on two analysis periods: the Worst 20% Average Winter Day, and the Annual Average Day. The emission inventories corresponding with these two aerosol/visibility analysis periods are the Average Winter Day and the Annual Average Day. To use a different analysis period, change the labels in the Tab 3.1 cells D15 and D16 for emission inventory labels, and in D19 and D20 for the aerosol and visibility analysis tables. These changes will be reflected in all of the other worksheets and reports.

All of the source-sector-based worksheets have one of two basic structures. Some of the worksheets containing input assumption data only have a single set of values that are applied to the calculations for both the winter and annual analyses. The modeling/forecasting worksheets have two sets of data. At the extreme top of a modeling/forecasting worksheet are text labels and notes describing the worksheet or Tab (Rows 1 through 6). Below this is the table containing the data and calculations for the Worst 20% Average Winter Day (Rows 7 through 80). At the bottom of the worksheet is the table containing the data and calculations for the Annual Average Day (Rows 83 through 156). Care should be taken NOT to insert or delete rows in the complex calculation worksheets without taking into consideration the potential alignment problems that might

result. Not having the worksheets “synchronized” on the same line basis can make debugging changes to the logic in the worksheets very difficult.

### **3.2 Financial Conversion Factors (Annualized Cost, Present Value)**

The financial assumptions, conversion factors, and calculation logic for averaging of costs is contained in Tab 3.2.

First, the levelized capital cost factor is developed. The BCAT uses the same assumptions that were used by the Grand Canyon Visibility Transport Commission. The capital cost effective rate (CCER) of 19.0% is made up of an assumption of 7.0% for the discount rate, and 12.0% for the added variable cost of capital (e.g. interest, insurance, property taxes). The annual levelized capital cost factor (LCCF) is dependent on the capital cost effective rate and the “useful” life of the capital investment. For the BCAT, this useful life (UL) is assumed to be 20 years (cell C18), and the LCCF is given by the formula:

$$LCCF = (CCER / (1 + CCER)) / ((1 - (1 / ((1 + CCER)^{UL}))) = 16.5\%$$

Thus, to convert a lump sum capital cost into an equivalent annual levelized cost, the capital cost is multiplied by a factor of 0.165. For example, a \$1,000,000 capital expenditure would equate to a \$165,000/year annual cost. Also note that the basis year for all cost figures is year 2000 dollars (cell C23).

The calculation of the total capital and annual operating and maintenance costs and levelized annual cost are performed in the table in Rows 29 through 39 of Tab 3.2. The Capital Expenditures in Row 31 are from the total capital figures in Row 80 of Tab 2.3.7, the input cost worksheet. The Annual Operating and Maintenance costs in Row 32 are from the total operating and maintenance costs in Row 80 of Tab 2.3.7.

Line 34 is a trigger line that determines the number of years that the annual operating and maintenance cost is applied to for the period. It is triggered on the basis of the “first” year any operating and maintenance cost is entered in Row 32. The number of applicable years is multiplied by the annual operating and maintenance cost to generate a total operating and maintenance cost for the analysis period, assuming a total of 20 years of annual cost. This row of values, that represent the total cost over the 20-year life, is divided by 20 and reported on Row 38 as the “average” annual operating and maintenance cost for the control option scenario. The sum of the capital expenditures in Row 31 is multiplied by the levelized annual capital cost factor of 0.165 and reported on Row 37. The sum of the Levelized Annual Capital Cost and Levelized Annual O & M costs on Rows 37 and 38 is reported on Row 39. This value is the control value reported in cell E59 of the assessment report (Tab 1.5) for the total levelized annual cost.

### **3.3 Source Sectors Included in the Analysis**

An analytical framework where “like” sources are grouped together is needed to assess the impact of a control option scenario on emissions, and subsequently on visibility and

cost. “Like” sources are those sources with similar emission producing behavior that could utilize the same or similar emission management technologies or programs.

The Maricopa Association of Governments had developed an extensive emission inventory for 1995 that was the basis for analytical work associated with development of the implementation plan for the PM-10 National Ambient Air Quality Standards needed to bring the area back into compliance with these standards. A summary breakdown of this inventory was the initial starting point for developing the final source sector list.

After reviewing this initial list, and consulting with the policy analysis committees of the Summit, several summary categories were broken out into their detailed components. The final source sector list is located in Tab 3.3 of the BCAT. Note that all of the source sector based worksheets throughout the BCAT refer to the labels in Tab 3.3 allowing easy changes to the names of the source sectors used in the analysis. Changing a source sector label in Tab 3.3 changes the corresponding line in all of the other worksheets.

### **3.4 Visibility Emission Inventory Pollutants and Aerosol Species**

For ease of maintenance, the labels associated with the pollutants in the inventories and ambient concentrations are summarized in tables in Tab 3.4. All detail worksheets refer to the labels in Tab 3.4 when this information is needed for column headers or row labels.

The aerosol species and gases that contribute to visibility impairment are summarized in Table 1 of Tab 3.4. The aerosol species and gases modeled for visibility include: ammonium sulfate, ammonium nitrate, organic carbon, elemental carbon, other fine material < 2.5 micron (soils/dusts), coarse material >2.5 micron and < 10 micron (soils/dusts), and nitrogen dioxide.

In order to predict the concentration of the above aerosol species and gases in the atmosphere, the emission inventory for atmospheric modeling must contain the pollutants associated with the primary emission of the above, or the pollutants that react in the atmosphere to create them. Table 2 of Tab 3.4 contains the speciated emission inventory pollutants of interest. These include: organic carbon, elemental carbon, other fine material < 2.5 micron (soils/dusts), coarse material >2.5 micron, oxides of nitrogen (that form ammonium nitrate and nitrogen dioxide), sulfur dioxide (that forms ammonium sulfate), ammonia, and volatile organic carbon compounds (which can in some instances form secondary organic carbon).

The input emission inventory used in the analysis is not a speciated emission inventory. Instead it is a traditional emission inventory used for implementation plan development for the PM-10 non-attainment planning process. The pollutants in the base inventories are summarized in Table 3 of Tab 3.4. These include: particulate matter < 10 microns, particulate matter < 2.5 microns, oxides of nitrogen, sulfur dioxide, ammonia, and volatile organic carbon compounds. The main difference between the speciated

inventory and the base inventory is that the particulate matter inventory is broken down into its components parts.

Finally, the conversion of the particulate matter < 2.5 into its components of interest is done using source sector specific speciation profiles. There are three components of interest in this analysis. The labels associated with these components are contained in Table 4 of Tab 3.4. To summarize, the component speciation factors needed for the BCAT are: organic carbon fraction of PM-2.5, elemental carbon fraction of PM-2.5, and other fine material (soil/dust) fraction of PM-2.5. For reference, the speciated inventory coarse material is computed as the difference between the base inventory PM-10 and PM-2.5.

### **3.5 1995 MAG Emission Inventory**

The Maricopa Association of Governments developed an implementation plan to remedy the non-attainment status of the area for the PM-10 National Ambient Air Quality Standard. A comprehensive emission inventory for 1995 was developed that was the starting point for the development of the implementation plan. The Summit adopted this 1995 MAG inventory as the starting point for long-range forecasts of emission and visibility patterns in the Phoenix area. This base emission inventory is located in Tab 3.5.

It should be noted that in the BCAT this worksheet contains static values. In the BCAT\_DEVELOPER, this worksheet refers to an import data worksheet (contained in Tab 5.2.1).

### **3.6 Source Sector PM-2.5 Emissions Inventory Speciation Factors**

In order to convert the MAG Emission Inventory to the speciated emissions of interest for visibility modeling, it is necessary to understand the composition of the PM-2.5 emissions. Each source sector has a different characteristic mix of the organic carbon, elemental carbon, and other fine material that makes up the total PM-2.5 emissions. These factors are known as speciation factors, and are expressed as a fraction of the PM-2.5 that is emitted as a particular component.

In addition to the standard speciation factors, a closure issue was noted between the mix of organic and elemental carbon in the speciated emission inventory, and the composition of fine particulate matter measured in the atmosphere. Based on a number of observations it was determined that the relative emissions of organic and elemental carbon from gasoline and diesel combustion sources was out of balance. An analysis was performed to determine a correction factor for gasoline and diesel combustion emissions that would accomplish two goals:

1. Balance the ratio of emission of elemental and organic carbon with the ratio measured on ambient air filter measurements, and
2. Ensure the overall PM-2.5 emission rate would match the original 1995 MAG Emission Inventory.

Based on this analysis, the mass emissions of gasoline and diesel sources were adjusted by a multiplicative factor to achieve the above objectives. Retaining the experimentally derived organic and elemental carbon fractions, the PM-2.5 mass emissions from gasoline combustion were increased (by a factor of 7.96) and the mass from diesel combustion was decreased (by a factor of 4.10 or 1/0.244). This adjustment is in effect recognizing that the emission projections from many mobile models understate the emissions from gasoline sources associated with high-emitters and off-cycle operation of the vehicles. The final speciation factors are located in Tab 3.6, along with the correction factors for gasoline/diesel sources.

It should be noted that Tab 3.6 of the BCAT contains a static table of values while the BCAT\_DEVELOPER contains an active calculation table in Tab 3.6 that refers to Tab 5.2.4, which contains the original imported speciation factors before gasoline/diesel correction.

### **3.7 Source Sector Overall Growth Rate Assumptions**

A key feature of the long-range forecasting methodology of the BCAT is its reliance on projections from econometric models of growth to simulate the overall demand for goods and services (or emission related activities) for each source sector. In the GCVTC work, this was referred to as the Source Sector Demand Index. In BCAT, we simply refer to it as the Growth Rate. Growth rates are expressed in terms relative to the 1995 base inventory. For 1995, the growth rate is set to 1.0. If industrial activity were to double from the 1995 level, the growth rate would be set to 2.0.

The emission modeling relies on separate treatment of “existing” sources (those that existed in 1995) that retire over time, and “new” sources (those that came online after 1995) that come online to satisfy the overall demand indicated by the growth rate. The BCAT allows for different emission characteristics for the existing and new sources.

The growth rate data used in the BCAT is the reference data used by MAG in the development of implementation plans and long-range projections. The projected growth from 1995 to 2003, 2006, 2010, 2015, and 2020 were provided. The growth rates for mobile on-road sources were derived from a comprehensive mobile modeling analysis. The growth rates for utilities were provided by Maricopa County.

The source sector growth rates are located in Tab 3.7. Only one set of growth rates are used in BCAT. That is, the same growth rates are used for winter and annual average days. Although they are referred to as growth rates, there are some source sectors where the growth rate is actually a reduction (long term = 0.5) meaning only half of the original emission related activity will be needed at that future time.

As with some other worksheets, the BCAT contains a static table of values for Tab 3.7, while the BCAT\_DEVELOPER refers to the data import sheet contained in Tab 5.2.2.

### **3.8 Source Sector Retirement Rate Assumptions for Existing Sources**

The second key “economic” driver in the development of emission forecasts is the assumed retirement of existing sources. The retirement rate is expressed as the cumulative fraction of the 1995 sources that have retired by some specified forecast year.

The GCVTC had an extensive analysis performed by Argonne National Laboratories to develop estimates of the retirement rates for a wide variety of source sectors. Although the source sectors used did not match exactly those used in the BCAT, a very close mapping of GCVTC retirement rates to the BCAT source sectors was achieved. The retirement rate assumptions are contained in Tab 3.8. In the BCAT, Tab 3.8 contains static values, while the BCAT\_DEVELOPER contains links to the import data worksheet in Tab 5.2.3.

### **3.9 Baseline Control Efficiencies for Existing and New Sources**

The BCAT was designed to allow for different control efficiencies for older “existing” sources and “new” sources. The term “existing sources” refers to those sources that were in existence in the base year inventory from which all forecasts are generated, that is, the 1995 MAG emission inventory. The term “new sources” refers to those sources that did not exist in 1995, but were brought online after the base year inventory, that is, post-1995 sources. Generally, the emission rate per unit of production from a new source is lower than an older source designed for the same purpose. This is due to the fact that many older sources were built before pollution controls were needed, or may have had a requirement to retrofit with reasonably available control technology, while newer sources must comply with more stringent new source performance standards, best available control technology, or lowest achievable emission rate requirements under new source review.

Because of limitations on available detailed information about existing and new source control efficiencies, and the need to assure that the long-range forecast from the BCAT for 2003 and 2006 matched the MAG projections, the control efficiencies that were developed for application in BCAT are composite efficiencies (applicable to both existing and new sources). If a need arises to fully utilize the existing/new source discrimination feature of the BCAT, it can be implemented for any particular source sector, or for all source sectors, where detailed control efficiency information for existing and new sources exists. Such treatment may be preferred, for example, if sources in a category had been allowed to operate without pollution control equipment or measures prior to 1995, and new sources permitted after 1995 were required to have pollution control equipment or measures. Mobile sources sectors would probably not benefit from such treatment since the sophisticated mobile source emission models include the technology turnover in their calculations.

#### **3.9.1 Baseline Control Efficiencies for Existing Sources**

The Baseline Forecast Scenario control efficiencies for existing sources are located in Tab 3.9.1. They are expressed as the “fraction” of emissions remaining after the effect of

the control is taken into consideration. In defining the control efficiencies, the 1995 reference point is important. The control efficiencies for future years for existing sources and for new sources all must be stated relative to the control efficiency used to characterize the 1995 control level.

The control efficiencies can be stated in an absolute or a relative sense. When using an absolute sense, the actual control efficiency for 1995 would be entered, and the control efficiencies for other periods would also be expressed in an absolute sense. For example, if the control efficiency of a device is 75% removal of the pollutant in 1995, but for new sources, a 90% removal would be appropriate, the entry for 1995 would be 0.25 representing that 25% of the uncontrolled emissions would still be emitted, and the new source would be 0.10 representing 10% of the uncontrolled emission would still be emitted. Because of complexity, it is sometimes more useful to express the base year control efficiency for a relatively “uncontrolled” source with a control efficiency of 1.0 and then scale all other control efficiencies to this value. In the case above where the new source would have 90% removal compared to the 75% removal of the 1995 existing source, the 1995 control efficiency could be stated as 1.0, while the new source is specified as 0.4 (40% of the 1995 emission rate). Since the ratio of the 1995 control efficiency to the other time period is used to “scale” the 1995 emission inventory to reflect the emissions from the other time period, either will work, as long as relative and absolute control efficiencies are not intermixed for a given source sector.

In the BCAT, Tab 3.9.1 is a static table of values. In the BCAT\_DEVELOPER Tab 3.9.1 was originally linked to the final frozen/adjusted control efficiencies (Tab 5.3.9-BFS-FROZEN-CTLEFF) derived from the extended analysis of control efficiencies described in Section 5.3 that did not include the most recent Tier-II standards. In the latest version, Tab 3.9.1 is linked to the control efficiencies reflecting these new standards (Tab 5.3.9-BFS\_2001\_CTLEFF).

### **3.9.2 Baseline Control Efficiencies for New Sources**

The Baseline Forecast Scenario control efficiencies for new sources are located in Tab 3.9.2. They are expressed as the “fraction” of emissions remaining after the effect of the control is taken into consideration. In defining the control efficiencies, the 1995 reference point is important. The control efficiencies for future years for new sources must be stated relative to the control efficiency used to characterize the 1995 control level. The reader is referred to the discussion in Section 3.9.1, above, for clarification of the use of absolute and relative control efficiencies.

In the BCAT, Tab 3.9.2 is a static table of values representing the relative control efficiencies of source sectors compared to the 1995 base year controls. In the BCAT\_DEVELOPER Tab 3.9.2 is linked to the same Tab 5.3.9 as described for existing sources. Because of the need to force closure with the MAG emission forecasts in 2003 and 2006, and the lack of detailed discriminatory control efficiencies between new and existing sources, the control efficiencies for new and existing sources were set to a composite average for the two types of sources.

### **3.9.3 Derivation of Baseline Control Efficiencies**

The derivation of the Baseline Forecast Scenario control efficiencies is described step by step in Section 5.3. The following is a summary of the key aspects of the derivation.

MAG provided detailed emission inventories for the 2003 and 2006 time periods based on the control projected to be implemented to bring the area into attainment with the PM-10 National Ambient Air Quality Standard. In addition, long-range mobile source modeling was performed to project emissions for on-road mobile sources using Mobile5, a standard USEPA model to project emissions from mobile sources. Maricopa County provided a detailed forecast of the emissions for the utility sector.

A Baseline Forecast Scenario using “unit” control efficiencies, that is, with efficiencies set to 1.0 for all years, was generated to establish a 1995 based control level forecast of emissions. The average control efficiencies for each source sector were computed for 2003 and 2006 and the other years for mobile and utility sources.

MAG provided composite control efficiencies for 2010, 2015, and 2020. These were combined into a table with the values computed above to generate an overall control efficiency matrix by source sector and year. Because of numerical round off errors, some control efficiencies were out of the expected range, that is, they were a number greater than 1.0, or the back calculated values for 2003 and 2006 were not consistent with the 2010-2020 values provided by MAG. A hand reconciliation and adjustment process was used to make final adjustments to the control efficiencies so they were internally consistent. These values were frozen, and used to provide the necessary input for Tabs 3.9.1 and 3.9.2.

An adjustment to this set of control efficiencies was developed to reflect the effects of the now final EPA Tier-II standards for diesel and heavy-duty gasoline engine and fuel standards and implemented in BCAT on January 10, 2001 (see Tabs 5.3.9 in BCAT\_DEVELOPER and refer to Section 5.3 for more details).

### **3.10 Air Quality Transfer Matrix / Extinction Efficiencies**

The majority of the computational logic within the BCAT is directed at generating emission forecasts, both for a Baseline Forecast Scenario, and the control option scenario being assessed. Once the forecast of emissions over time is constructed, they can be converted to projections of atmospheric concentrations of the aerosols and gases that cause visibility impairment through the use of an air quality model, or conversion factors, known as transfer coefficients, developed from an air quality model. After the emission of pollutants is converted to an estimate of the concentration of the pollutants in the air, these estimates can be converted to estimates of the light extinction coefficient of the atmosphere, that is, the quantitative measure of how much light is extinguished as it travels through the air. The following sections address the air quality and light extinction modeling performed in the BCAT.

### **3.10.1 Air Quality Transfer Coefficients and Background Values**

An air quality model defines, in a quantitative sense, the atmospheric processes that govern the transport, dispersion, chemical formation and decay, and deposition of pollutants resulting in projections of the concentration of the pollutants in the air. Since running a robust model within the BCAT is beyond its intended purpose, and since, over small ranges of change, the change in emissions is almost linearly related to the change in concentrations, the BCAT uses Air Quality Transfer Coefficients to convert emission rates into atmospheric concentrations. These Transfer Coefficients are found on Row 16 of Tab 3.10. These values were derived from a simple speciated-rollback modeling approach, discussed later, but could have been developed with a more rigorous model and loaded into the appropriate cells on Row 16. The emission rate (expressed in kilograms per day) when multiplied by the transfer coefficient yields the ambient concentration of the pollutant of interest (expressed in micrograms per cubic meter of air). The transfer coefficients for the Worst 20% Average Winter Day (Row 16) are different than the Annual Average Day (Row 52). Tab 3.10 includes both of these sets of values for use in the appropriate calculation sections of the worksheets. The BCAT requires (or allows for use of) the following transfer coefficients:

1. Sulfur Dioxide Gas converted to Ammonium Sulfate Particles
2. Oxides of Nitrogen Gas converted to Ammonium Nitrate Particles
3. Organic Carbon Particles
4. Volatile Organic Carbon Gases converted to Organic Carbon Particles
5. Elemental Carbon Particles
6. Other Fine Material (Soils/Dusts < 2.5 micron)
7. Coarse Material (Soils/Dusts > 2.5 micron and < 10 micron)
8. Oxides of Nitrogen Gas converted to Nitrogen Dioxide Gas (ppb)

In addition to the concentration of particulates from the emission inventory, there are also contributions from sources outside the modeling domain. These are associated with long-range transport. An estimate of the background concentration for purposes of this analysis were derived by examining data from the Chiricahua National Monument monitoring data in southeast Arizona. The background values are separately treated in the model to ensure that the overall light extinction includes the contributions from sources outside the control region. These are located on Row 19 of Tab 3.10.

The Transfer Coefficients used in the BCAT were derived from a simple speciated roll-back approach. The assumption is made that, except for the contribution from “background” sources entered separately, the particulate measurement is directly and linearly linked to the emission inventory for each of the aerosol species being studied. It has been acknowledged that this may or may not be correct by the ITAG and the Summit, but for the purpose of the Summit’s assessment this would be applied since more sophisticated modeling was not available at the time. The computation of the Transfer Coefficients is simply a division of the emission inventory for the pollutant in question into the difference between the measured particulate concentration and the background assumption, on a species by species basis. It should be noted that, at any time, the Transfer Coefficient values used in the computation of aerosol concentrations and

resulting visibility could be replaced with manually entered ratios derived from more sophisticated modeling and analysis.

### **3.10.2 Light Extinction Efficiencies and Relative Humidity**

The ability of particles and gases to interfere with light as it passes through the atmosphere is well documented. Within the BCAT there are two recommended models that allow conversion of ambient concentration data into light extinction estimates. The first, and preferred method, is that used by the IMPROVE network. The second is a “Phoenix” specific model that was developed as part of an extensive field study in the Phoenix area. Changing cell H5 of Tab 3.10 toggles which of these extinction efficiency models are used. The default value of “1” is associated with the IMPROVE model. If a “2” is entered into cell H5, the model uses the Phoenix specific light extinction model.

### **3.11 Intensity Index for Sensitivity Studies**

Occasionally it is necessary to investigate the sensitivity of the modeling calculations to various assumptions. For instance, there may be a suspicion that the emissions from a particular source sector are under stated or over stated. The intensity index can be used to shed light on how sensitive the results of assessment are to changes in the underlying assumptions. Tab 3.11 contains a matrix of the value “1.0”. The intensity index is a multiplicative factor that is brought into the end of the emission projection calculations and is applied on a source sector cell by source sector cell basis. If one wished to know the effect of having a 100% error in the emission inventory for a given source sector, one would enter “2.0” in each cell on the line. This will result in a doubling of the contribution, for both the baseline and the effect of the control option scenario.

## **4.0 Key Calculations and Results**

This section of the report explains the sequence of calculations that is performed by the BCAT to generate the projected emissions, aerosol concentrations, and light extinction for the Baseline Forecast Scenario and the control option scenario, and restates the calculations used to compare the scenarios found in the assessment report. Most of the key “assumption” data was described in Section 3. This section explains how the results are built up from these starting assumption worksheets. For the source sector detail worksheets (Tabs), the relevant equation for a cell is included in the documentation for reference. It is assumed that the reader is familiar with how cell equations are constructed.

### **4.1 Baseline Forecast Scenario (BFS)**

The Baseline Forecast Scenario (BFS) is the reference scenario to which all control option scenarios are compared. The BFS is considered a scenario which reasonably reflects the expected changes in economic activity and population over the time horizon of the study and includes all air pollution, and measures that can affect air pollution, that are required under current federal, state, and local regulations and requirements. Proposed standards that have not been finalized are not included in the BFS.

#### **4.1.1 Baseline Projected Utilization of Existing Sources**

The first step in the calculation sequence is to determine the projected utilization of “existing” sources by source sector. This is done by examining the growth rate assumption and the retirement rate assumption. Tab 4.1.1 performs the calculation of the projected utilization of existing sources for each source sector for each forecast year. This analysis is done only once for the “Annual Average” and applies to both winter and annual projections. Calculations are done at the detail source sector level with summary totals built up from the detail and reported as “averages.”

The calculation recognizes that retirement rates could result in no existing sources remaining, or that projected utilization could be limited to below the output capacity of the existing sources. For this reason, the calculation logic is structured as a two-step MIN/MAX calculation:

1. Determine the Maximum of (1-fraction retired) and 0. Existing Utilization may not be greater than this value, nor less than 0.0 (Note: fraction retired is from Tab 3.8). To some extent, this test is to ensure that a data entry error did not result in “over” retiring existing sources that would generate a “negative” utilization.
2. Determine the Minimum of the value from Step 1 above, and the projected growth rate. Existing Utilization may be limited to the projected growth rate if it is less than the fraction of un-retired sources still available (Note: growth rate is from Tab 3.7).

Tab 4.1.1, Cell B12: = MIN (MAX ((1-'3.8-Retire'!B12), 0),'3.7-Grow'!B12)

#### **4.1.2 Baseline Projected Utilization of New Sources**

After the fraction of the overall demand for a source sector provided by “existing” sources has been determined in Tab 4.1.1, the amount of activity from the “new” sources in the source sector can be determined. The utilization of the “new” sources in the source sector is simply the difference between the overall sector demand (or growth rate in Tab 3.7) and any utilization of “existing” sources determined above in Tab 4.1.1.

Tab 4.1.2, Cell B12: = '3.7-Grow'!B12-'4.1.1-ExUtil'!B12

#### **4.1.3 Baseline Projected Emissions for Existing Sources**

After the utilization has been determined for “existing” and “new” sources in the source sector, the next step is to project the emissions from the “existing” sources for the average winter and annual days. This calculation involves multiplying the base 1995 inventory value (Tab 3.5) by the ratio of the existing source control efficiency in the forecast year divided by the existing source control efficiency in the 1995 base year (Tab 3.9.1), then multiplying the result by the utilization of existing sources (Tab 4.1.1), and finally, multiplying the whole quantity by the Intensity Index used for sensitivity analysis (Tab 3.11, usually 1.0). The calculations are performed for each source sector, for each pollutant in the 1995 base inventory, and for each year in the analysis.

Tab 4.1.3, Cell C12 (Winter): = '3.5-INV95'!\$B12\*('3.9.1-ExEffc'!C12/'3.9.1-ExEffc'!\$B12)\*'4.1.1-ExUtil'!C12\*'3.11-IntIndx'!C12

Tab 4.1.3, Cell C88 (Annual): = '3.5-INV95'!\$B88\*('3.9.1-ExEffc'!C88/'3.9.1-ExEffc'!\$B88)\*'4.1.1-ExUtil'!C12\*'3.11-IntIndx'!C88

#### **4.1.4 Baseline Projected Emissions for New Sources**

A similar calculation is then performed to project the emissions from the “new” sources by source sector, pollutant, and forecast year for both the winter and annual average days. Again, this calculation involves multiplying the base 1995 inventory value (Tab 3.5) by the ratio of the new source control efficiency in the forecast year (Tab 3.9.2) divided by the existing source control efficiency in the 1995 base year (Tab 3.9.1), then multiplying the result by the utilization of new sources (Tab 4.1.2), and finally, multiplying the whole quantity by the Intensity Index used for sensitivity analysis (Tab 3.11, usually 1.0).

Tab 4.1.4, Cell B12 (Winter): = '3.5-INV95'!\$B12\*('3.9.2-NwEffc'!B12/'3.9.1-ExEffc'!\$B12)\*'4.1.2-NwUtil'!B12\*'3.11-IntIndx'!B12

Tab 4.1.4, Cell B88 (Annual): = '3.5-INV95'!\$B88\*('3.9.2-NwEffc'!B88/'3.9.1-ExEffc'!\$B88)\*'4.1.2-NwUtil'!B12\*'3.11-IntIndx'!B88

#### **4.1.5 Baseline Projected Total Emissions**

After the emissions from the “existing” sources (Tab 4.1.3) and the “new” sources (Tab 4.1.4) have been computed separately, the total emissions for the source sector are computed as the sum of the two components.

Tab 4.1.5, Cell B12 (Winter): = '4.1.3-ExEmi'!B12+'4.1.4-NwEmi'!B12

Tab 4.1.5, Cell B88 (Annual): = '4.1.3-ExEmi'!B88+'4.1.4-NwEmi'!B88

#### **4.1.6 Baseline Projected Speciated Emissions**

After the total emissions for the Baseline Forecast Scenario are computed, the base emissions forecast can be converted to the speciated emission forecast needed to compute the concentration of particles and gases related to visibility. The speciated emission inventory is contained in Tab 4.1.6. There are four sets of columns that are “calculated” from base inventory data, and the rest of the columns are simply a copy of the base inventory. These calculations are performed for both the winter and annual average days, although only the winter will be included in the example equations below.

The first set of speciation calculations relates to the “fractionation” of the PM-2.5 inventory contained in columns H through M of Tab 4.1.5. The PM-2.5 values are converted in Tab 4.1.6 into Organic Carbon (columns B-G), Elemental Carbon (columns H-M), and Other Fine Material (columns N-S). These values are created by multiplying the PM-2.5 values contained in Tab 4.1.5 by the appropriate speciation factors in Tab 3.6 for a given source sector.

Tab 4.1.6, Cell B12 (Organic Carbon): = '3.6-SpecFct'!\$B12\*'4.1.5-BFS\_Emis'!H12

Tab 4.1.6, Cell H12 (Elemental Carbon): = '3.6-SpecFct'!\$C12\*'4.1.5-BFS\_Emis'!H12

Tab 4.1.6, Cell N12 (Other Fine Mat'l): = '3.6-SpecFct'!\$D12\*'4.1.5-BFS\_Emis'!H12

The second speciation calculation relates to the determination of the coarse fraction of the PM-10 contained in columns B-G of Tab 4.1.5. This is estimated by subtracting the PM-2.5 from the PM-10 resulting in a value that represents the coarser part of PM-10. Because numerical round off could result in PM-2.5 being greater than PM-10, the estimate of the Coarse Material value is range checked to make sure it is greater than or equal to zero.

Tab 4.1.6, Cell T12 (Coarse Material): = MAX('4.1.5-BFS\_Emis'!B12-'4.1.5-BFS\_Emis'!H12,0)

Note: Row 12 refers to winter; Row 88 has comparable equations for annual.

#### **4.1.7 Baseline Projected Aerosol Concentration**

The projected aerosol concentrations are computed from the speciated emission inventory (Tab 4.1.6) and the transfer coefficients (Tab 3.10) for the Worst 20% Average Winter Day, and the Annual Average Day. The mapping of the transfer coefficients to the speciated pollutants in the inventory was summarized in Tab 3.10. Tab 4.1.7 is organized by the aerosol species and values are expressed in micrograms per cubic meter for particulates, and parts per billion for Nitrogen Dioxide gas. Extra total lines were added at line 81 and line 157, to add the background concentrations to the total from model predictions in order to provide a direct comparison to the filter measurements.

The equations of interest for the winter calculations are as follows:

Tab 4.1.7, Cell B12 (Ammonium Sulfate):

$$='3.10-TC\&Bkgr'!\$D\$16*'4.1.6-BFS\_SpecInv'!AF12$$

Tab 4.1.7, Cell H12 (Ammonium Nitrate):

$$='3.10-TC\&Bkgr'!\$E\$16*'4.1.6-BFS\_SpecInv'!Z12$$

Tab 4.1.7, Cell N12 (Organic Carbon):

$$='3.10-TC\&Bkgr'!\$F\$16*'4.1.6-BFS\_SpecInv'!B12+'3.10-TC\&Bkgr'!\$G\$16*'4.1.6-BFS\_SpecInv'!AR12$$

Tab 4.1.7, Cell T12 (Elemental Carbon):

$$=+'3.10-TC\&Bkgr'!\$H\$16*'4.1.6-BFS\_SpecInv'!H12$$

Tab 4.1.7, Cell Z12 (Other Fine Mat'l):

$$='3.10-TC\&Bkgr'!\$I\$16*'4.1.6-BFS\_SpecInv'!N12$$

Tab 4.1.7, Cell AF12 (Coarse Material):

$$='3.10-TC\&Bkgr'!\$J\$16*'4.1.6-BFS\_SpecInv'!T12$$

Tab 4.1.7, Cell AL12 (Nitrogen Dioxide):

$$='3.10-TC\&Bkgr'!\$K\$16*'4.1.6-BFS\_SpecInv'!Z12$$

#### **4.1.8 Baseline Projected Visibility (Light Extinction)**

The final step in the detailed source sector based calculations is the calculation of the light extinction coefficient for each source sector by pollutant and forecast year. The aerosol concentrations in Tab 4.1.7 are multiplied by the aerosol specific light extinction efficiencies and relative humidity attenuation factors to generate the projected light extinction in inverse Megameters. Extra columns at the right end of the table summarize the total light extinction for all aerosols for a given source sector. The calculations are done for both the winter and annual average. The key equations for the calculations are:

Tab 4.1.8, Cell B12 (Ammonium Sulfate):

=4.1.7-Aero!'B12\*'3.10-TC&Bkgr!\$D\$30\*'3.10-TC&Bkgr!\$D\$31

Tab 4.1.8, Cell H12 (Ammonium Nitrate):

=4.1.7-Aero!'H12\*'3.10-TC&Bkgr!\$E\$30\*'3.10-TC&Bkgr!\$E\$31

Tab 4.1.8, Cell N12 (Organic Carbon):

=4.1.7-Aero!'N12\*'3.10-TC&Bkgr!\$F\$30\*'3.10-TC&Bkgr!\$F\$31

Tab 4.1.8, Cell T12 (Elemental Carbon):

=4.1.7-Aero!'T12\*'3.10-TC&Bkgr!\$H\$30\*'3.10-TC&Bkgr!\$H\$31

Tab 4.1.8, Cell Z12 (Other Fine Mat'l):

=4.1.7-Aero!'Z12\*'3.10-TC&Bkgr!\$I\$30\*'3.10-TC&Bkgr!\$I\$31

Tab 4.1.8, Cell AF12 (Coarse Material):

=4.1.7-Aero!'AF12\*'3.10-TC&Bkgr!\$J\$30\*'3.10-TC&Bkgr!\$J\$31

Tab 4.1.8, Cell AL12 (Nitrogen Dioxide):

=4.1.7-Aero!'AL12\*'3.10-TC&Bkgr!\$K\$30\*'3.10-TC&Bkgr!\$K\$31

Tab 4.1.8, Cell AR12 (Total Extinction):

=B12+H12+N12+T12+Z12+AF12+AL12

## **4.2 Control Option Scenario**

The calculations for a control option scenario are very similar to those for the Baseline Forecast Scenario described in Section 4.1. The key differences are related to the generation of adjustments to the emissions forecasts based on adjustments in growth rates, retirement rates, control efficiencies, and/or direct specification of changes in emission rates. This section addresses the development of the source sector detail data for the control option scenario. The input of data characterizing the emission changes and costs for the control option scenario is described fully in Section 2, above.

### **4.2.1 Control Option Scenario Adjusted Utilization of Sources**

Unlike the BFS, in the control option scenario, the first step is to compute the “adjusted” growth rates and “adjusted” retirement rates. If no adjustments have been entered for processing, then the control option scenario and BFS growth and retirement rates will be the same. Based on the adjusted growth and retirement rates, the “existing” and “new” source utilization for the source sector is determined. Tab 4.2.1 is organized with 4 sets of columns representing (in order) the adjusted growth rates, the adjusted retirement rates, the adjusted “existing” source utilization, and adjusted “new” source utilization. These will be discussed more fully in that order.

The adjusted growth rate (columns B-G) is computed by multiplying the baseline growth rate (Tab 3.7) by the growth rate adjustment (Tab 2.3.3).

Tab 4.2.1, Cell B12 (Adj. Growth) =+'2.3.3-Grow&Ret'!B12\*'3.7-Grow'!B12

The adjusted retirement rate (columns H-M) is computed by multiplying the baseline retirement rate (Tab 3.8) by the retirement rate adjustment (Tab 2.3.3).

Tab 4.2.1, Cell H12 (Adj. Retirement) =+'2.3.3-Grow&Ret'!H12\*'3.8-Retire'!B12

The adjusted “existing” source utilization (columns N-S) is calculated in the same way as the “existing” source utilization was computed for the BFS in Tab 4.1.1. A compound MIN/MAX calculation is used. First the existing utilization is limited to the projected growth rate if it is less than the fraction of un-retired sources still available. Then utilization must be greater than or equal to 0.0.

Tab 4.2.1, Cell N12 (Adj. Exist. Util.)  
=MAX(MIN(1-'4.2.1-CtlUtil'!H12,'4.2.1-CtlUtil'!B12),0)

Finally, the adjusted “new” source utilization (columns T-Y) is computed as the difference between the adjusted growth rate and the adjusted “existing” source utilization.

Tab 4.2.1, Cell T12 (Adj. New Util.) ='4.2.1-CtlUtil'!B12-'4.2.1-CtlUtil'!N12

## **4.2.2 Control Option Scenario Adjusted Control Efficiencies**

The most common method of specifying the emission change for a control option scenario is to adjust the “existing” source control efficiency, the “new” source control efficiency, or both. The adjusted control efficiencies for “existing” sources are computed in Tab 4.2.2-ExEff, while adjusted control efficiencies for “new” sources are computed in Tab 4.2.2-NwEff. As noted above, the control efficiencies are expressed as the “fraction” of emissions remaining after the effect of the control is taken into consideration, relative to the existing source control efficiency specified for the base year, 1995.

The adjusted “existing” source control efficiency is computed by multiplying the BFS “existing” source control efficiency (Tab 3.9.1) by the control scenario existing source control efficiency adjustment factor (Tab 2.3.4).

Tab 4.2.2-ExEff, Cell B12 : = '2.3.4-ExEffAdj'!B12\*'3.9.1-ExEffc'!B12

The adjusted “new” source control efficiency is computed by multiplying the BFS “new” source control efficiency (Tab 3.9.2) by the control option scenario new source control efficiency adjustment factor (Tab 2.3.5).

Tab 4.2.2-NwEff, Cell B12 : = '2.3.5-NwEffAdj'!B12\*'3.9.2-NwEffc'!B12

#### **4.2.3 Control Option Scenario Projected Emissions for Existing Sources**

The calculation of the control option scenario projected emissions for existing sources parallels the calculation for the BFS. This calculation involves multiplying the base 1995 inventory value (Tab 3.5) by the ratio of the adjusted existing source control efficiency in the forecast year divided by the existing source control efficiency in the 1995 base year (Tab 4.2.2-ExEff), then multiplying the result by the utilization of existing sources (Tab 4.2.1), then multiplying the whole quantity by the Intensity Index used for sensitivity analysis (Tab 3.11, usually 1.0), and finally, unlike the BFS, adding the emission inventory adjustment (Tab 2.3.6).

Note that since the emission inventory adjustment from Tab 2.3.6 is taken up in the “existing” source contribution, it may be possible for the resulting value to be negative. This is due to the fact that “existing” sources decline over time due to retirement. This is not a problem computationally, since these “existing” source emissions are added to the “new” source emissions when calculating the total emissions for the control option scenario. The calculations are performed for each source sector, for each pollutant in the 1995 base inventory, and for each year in the analysis for both the winter and annual average conditions.

Tab 4.2.3, Cell C12: = '3.5-INV95'!\$B12\*('4.2.2-ExEff'!C12/'4.2.2-ExEff'!\$B12)\*'4.2.1-CtlUtil'!O12\*'3.11-IntIndx'!C12+'2.3.6-EmiAdj'!C12

#### **4.2.4 Control Option Scenario Projected Emissions for New Sources**

The calculation of the control option scenario projected emissions for a new source is similar to those for the existing sources, except that the emission inventory adjustment from Tab 2.3.6 is not included. This calculation involves multiplying the base 1995 inventory value (Tab 3.5) by the ratio of the adjusted new source control efficiency in the forecast year (Tab 4.2.2-NwEff) divided by the existing source control efficiency in the 1995 base year (Tab 4.2.2-ExEff), then multiplying the result by the utilization of new sources (Tab 4.2.1), and finally, multiplying the whole quantity by the Intensity Index used for sensitivity analysis (Tab 3.11, usually 1.0). As with existing sources, these calculations are performed for each source sector, for each pollutant in the 1995 base inventory, and for each year in the analysis for both the winter and annual average conditions.

Tab 4.2.4, Cell B12: = '3.5-INV95'!\$B12\*('4.2.2-NwEff'!B12/'4.2.2-ExEff'!\$B12)\*'4.2.1-CtlUtil'!T12\*'3.11-IntIndx'!B12

#### **4.2.5 Control Option Scenario Projected Total Emissions**

Once the emission contribution from the “existing” sources and the “new” sources in the source sector have been computed separately, the total emissions are computed as the sum of the two components.

Tab 4.2.5, Cell B12 (Winter): = '4.2.3-ExEmi'!B12+'4.2.4-NwEmi'!B12

#### **4.2.6 Control Option Scenario Projected Speciated Emissions**

After the total emissions for the control option scenario are computed, they are converted to the speciated emission inventory needed to compute the concentration of particles and gases related to visibility. The control option scenario projected speciated emissions are contained in Tab 4.2.6. The same approach is taken for the speciation of the control option scenario as was performed for the BFS (See Section 4.1.6 for a discussion of the approach).

The relevant equations for the “fractionation” of the PM-2.5 inventory contained in columns H through M of Tab 4.2.6 are:

Tab 4.2.6, Cell B12 (Organic Carbon): = '3.6-SpecFct'!\$B12\*'4.2.5-COptEmi'!H12

Tab 4.2.6, Cell H12 (Elemental Carbon): = '3.6-SpecFct'!\$C12\*'4.2.5-COptEmi'!H12

Tab 4.2.6, Cell N12 (Other Fine Mat'l): = '3.6-SpecFct'!\$D12\*'4.2.5-COptEmi'!H12

The relevant equations for the determination of the Coarse Material fraction is:

Tab 4.2.6, Cell T12 (Coarse Material):  
=MAX('4.2.5-COptEmi'!B12-'4.2.5-COptEmi'!H12,0)

#### **4.2.7 Control Option Scenario Projected Aerosol Concentration**

The projected aerosol concentrations are computed from the speciated emission inventory (Tab 4.2.6) and the transfer coefficients (Tab 3.10) for the Worst 20% Average Winter Day, and the Annual Average Day. The mapping of the transfer coefficients to the speciated pollutants in the inventory was summarized in Tab 3.10. Tab 4.2.7 is organized by the aerosol species and values are expressed in micrograms per cubic meter for particulates, and parts per billion for Nitrogen Dioxide gas. Extra total lines were added at line 81 and line 157, to add the background concentrations to the total from model predictions in order to provide a direct comparison to the filter measurements.

The equations of interest for the winter calculations are as follows (note that the \$ on the cell references below indicate an absolute reference and will be the same column and row for all cells in the worksheet, while the other relative cell reference will change for each row and column):

Tab 4.2.7, Cell B12 (Ammonium Sulfate):  
='3.10-TC&Bkgr'!\$D\$16\*'4.2.6-COpt\_SpecInv'!AF12

Tab 4.2.7, Cell H12 (Ammonium Nitrate):  
='3.10-TC&Bkgr'!\$E\$16\*'4.2.6-COpt\_SpecInv'!Z12

Tab 4.2.7, Cell N12 (Organic Carbon):

$$='3.10-TC\&Bkgr'!\$F\$16*4.2.6-COpt\_SpecInv'!B12+'3.10-TC\&Bkgr'!\$G\$16*4.2.6-COpt\_SpecInv'!AR12$$

Tab 4.2.7, Cell T12 (Elemental Carbon):

$$='3.10-TC\&Bkgr'!\$H\$16*4.2.6-COpt\_SpecInv'!H12$$

Tab 4.2.7, Cell Z12 (Other Fine Mat'l):

$$='3.10-TC\&Bkgr'!\$I\$16*4.2.6-COpt\_SpecInv'!N12$$

Tab 4.2.7, Cell AF12 (Coarse Material):

$$='3.10-TC\&Bkgr'!\$J\$16*4.2.6-COpt\_SpecInv'!T12$$

Tab 4.2.7, Cell AL12 (Nitrogen Dioxide):

$$='3.10-TC\&Bkgr'!\$K\$16*4.2.6-COpt\_SpecInv'!Z12$$

#### **4.2.8 Control Option Scenario Projected Visibility (Light Extinction)**

The final step in the detailed source sector based calculations is the calculation of the light extinction coefficient for each source sector by pollutant and forecast year. The projected light extinction (in inverse megameters) is calculated by multiplying aerosol concentrations in Tab 4.2.7 by the aerosol specific light extinction efficiencies and relative humidity attenuation factors.

Extra columns at the right end of the table summarize the total light extinction for all aerosols for a given source sector. The calculations are done for both the winter and annual average. The key equations for the calculations are:

Tab 4.2.8, Cell B12 (Ammonium Sulfate):

$$='4.2.7-Aero'!B12*3.10-TC\&Bkgr'!\$D\$30*3.10-TC\&Bkgr'!\$D\$31$$

Tab 4.2.8, Cell H12 (Ammonium Nitrate):

$$='4.2.7-Aero'!H12*3.10-TC\&Bkgr'!\$E\$30*3.10-TC\&Bkgr'!\$E\$31$$

Tab 4.2.8, Cell N12 (Organic Carbon):

$$='4.2.7-Aero'!N12*3.10-TC\&Bkgr'!\$F\$30*3.10-TC\&Bkgr'!\$F\$31$$

Tab 4.2.8, Cell T12 (Elemental Carbon):

$$='4.2.7-Aero'!T12*3.10-TC\&Bkgr'!\$H\$30*3.10-TC\&Bkgr'!\$H\$31$$

Tab 4.2.8, Cell Z12 (Other Fine Mat'l):

$$='4.2.7-Aero'!Z12*3.10-TC\&Bkgr'!\$I\$30*3.10-TC\&Bkgr'!\$I\$31$$

Tab 4.2.8, Cell AF12 (Coarse Material):

$$='4.2.7-Aero'!AF12*3.10-TC\&Bkgr'!\$J\$30*3.10-TC\&Bkgr'!\$J\$31$$

Tab 4.2.8, Cell AL12 (Nitrogen Dioxide):

=4.2.7-Aero'!AL12\*3.10-TC&Bkgr'!\$K\$30\*3.10-TC&Bkgr'!\$K\$31

Tab 4.2.8, Cell AR12 (Total Extinction):

=B12+H12+N12+T12+Z12+AF12+AL12

#### **4.2.9 Control Option Scenario Emission Change Detail**

There may be cases where source sector specific emission changes between the control option scenario and the Baseline Forecast Scenario are needed. For instance, when combining the effects of several control option scenarios together, one option would be to enter the source sector emission changes for each sector directly, rather than characterizing control efficiency changes. The source sector detail emission change report in Tab 4.2.9 provides this information. The difference is calculated on a source sector cell basis as the difference between the BFS total emissions (4.1.5) and the control option total emissions (4.2.5)

Tab 4.2.9, Cell B12 =4.2.5-COptEmi'!B12-4.1.5-BFS\_Emis'!B12

### **4.3 Comparison of Control Option Scenario to Baseline Forecast**

The comparison of the control option scenario to the Baseline Forecast Scenario is performed in the Control Scenario Assessment Report (Tab 1.5). Section 1.5 of this document provides an overview of its content and interpretation. Section 2.1 of this document provides a detailed explanation of the sources of data and calculations performed. The reader is directed to these sections for a complete description of the comparison process.

### **4.4 Audit Sheet**

When working with a workbook model as large as BCAT it is sometimes difficult to locate problems with the equations and references when an error is accidentally introduced. There are also times when one wishes to quickly be able to see the difference between the control option scenario and the Baseline Forecast Scenario, just to satisfy one's curiosity.

The BCAT contains an audit sheet (Tab 4.4) to provide the capability to see the difference between the control option scenario and the Baseline Forecast Scenario quickly. This spreadsheet restates the grand totals for the winter and annual analyses for: the emission forecast, the speciated emission forecast, the aerosol concentrations, and the light extinction coefficients. A "pair" of lines represents the BFS and control option scenario for the same parameter. There is a "pair" for winter, and a "pair" for Annual.

Under each pair of lines, there is a line labeled "AUDIT". This audit line contains a logic test comparing the values in the BFS and control option results located in the two

cells above it. If the two values are the same, the cell displays as an empty cell. If the two values are not the same, “DIFF” appears in the cell, flagging the user that there is a difference between the cells.

The BCAT is not packaged with input “adjustments” for the control option scenario. Input “adjustments” are omitted to minimize confusion when entering data (i.e. so additional data deletion is not necessary before entering a control option scenario). The results from the control option scenario and BFS are the same when the BCAT is in this state. A check of the Audit sheet will identify where in the calculation scheme an out of balance situation occurs.

The Audit Sheet also can be used to verify that differences between the control option scenario and the BFS exist. It is recommended that the audit sheet be reviewed after a control option scenario has been set up to provide assurance that changes were in fact entered correctly.



## **5.0 Enhancing and Maintaining BCAT: Developer's Version**

The Brown Cloud Assessment Tool (BCAT) contains the worksheets necessary for the operation of the system, but excludes several sheets that were used during development to support layout and design, and to develop certain data tables that are static (not changing) during the operation of the model. However, one interested in modifying or enhancing the BCAT would need access to a version that includes these additional worksheets.

The BCAT\_DEVELOPER is the version of the assessment tool that contains these extra worksheets. Because of the number of the worksheets, the total file size of BCAT\_DEVELOPER is almost 19 megabytes. By contrast, the BCAT file is only 12 megabytes in size, because it contains only the 39 worksheets necessary to perform an analysis. Because each control option scenario requires saving a copy of the BCAT with the control option scenario data, this smaller file saves 7 megabytes per scenario when running assessments.

This section describes the various working tables used in the construction of the BCAT. It also provides guidance on how to make future enhancements to the BCAT and how to rebuild BCAT from BCAT\_DEVELOPER.

### **5.1 Worksheet Layout Master Sheets**

During the initial design and layout of the BCAT, the need for several different types of detailed calculation worksheets was identified. It was recognized that the size of the worksheets would make it difficult to locate items of interest. As such, the worksheets were designed with standardized color highlighting and structures to aid in their use.

A number of different types of worksheets would be needed depending on the data content or the columns. Prototype worksheets (including formatting but not calculation logic) were developed for each of the different worksheet types needed. These early design format worksheets have been retained and are included as a separate file (BCAT\_WORKSHEET\_TEMPLATES) as Tabs 5.1. There are a total of eight worksheets in this group. They have no active role in the BCAT and are simply included for reference since they appeared in the proto-type version of BCAT.

### **5.2 Data Import Sheets**

During the assembly of the prototype of BCAT, the test data was used to populate the data tables in Tabs 3.5 to 3.9.2. When these data became available, they were imported to separate worksheets at the end of the workbook, and the cells in Tabs 3.5 to 3.9.2 modified from a static test value to an equation referenced to the corresponding cell of the data import worksheets. This was to avoid any problems with equation linkages in the main processing logic, and allow rapid changes to the input data tables as new data became available. In BCAT\_DEVELOPER, Tabs 5.2 are the actual source of the input data used in the calculations. In BCAT, the raw data in Tabs 5.2 were frozen and loaded

into the 3.5 to 3.9.2 tabs. For a discussion of the process of converting BCAT\_DEVELOPER to BCAT see Section 5.4, below.

### **5.2.1 Import MAG 1995 Base Inventory**

The Maricopa Association of Governments (MAG) Annual Average 1995 Emission Inventory used for the development of the PM-10 State Implementation Plan was the basis for deriving emission forecasts in the BCAT. This inventory is imported in Tab 5.2.1 and referred to by Tab 3.5. Adjustments to the base inventory to develop the winter average emissions are noted at the bottom of Tab 5.2.1 (Rows 159-195). Adjustments were made for non-utility point sources and process fugitives and winter emissions from on-road mobile sources. The emissions from the National Emissions Trends (NET) inventory, with appropriate adjustments were used in place of the original MAG emissions. Also, better information for utility point sources from Maricopa County was used in place of the original MAG emissions.

### **5.2.2 Import Source Sector Overall Growth Rate Assumptions**

Tab 5.2.2 contains the imported growth rate assumptions for the various source sectors. The growth rates were derived from a variety of sources. MAG provided the majority of the growth factors for the source sectors. These were generally tied to population, employment, agricultural land area, developed land area, or undeveloped land area depending on the source sector. The source of the assumption for any particular source sector is noted in Column H of the worksheet.

The growth rates for the utility sector were provided by Maricopa County based on projected development of utility sources provided by the major utilities in the area. The projections for the growth factors for mobile sources were derived from Vehicle Miles Traveled (VMT) projections derived from comprehensive mobile source modeling performed by MAG. The VMT activity data used to derive the mobile source growth factors is in Rows 99 to 107 of Tab 5.2.2.

### **5.2.3 Import Source Sector Retirement Rate for Existing Sources**

The retirement rates for the source sectors were developed from the work performed by Argonne National Laboratories for the Grand Canyon Visibility Transport Commission. The values for retirement rates are imported into Tab 5.2.3 and referred to by Tab 3.8. The original retirement factors for the GCVTC were on decade intervals between 1990 and 2040. These values were interpolated to the analysis years of interest to the Summit.

Not all source sectors were assigned retirement rates. These include the on-road mobile sources (the retirement effect is included in the mobile model), and some area and off road categories. This simply means that a “technology turnover” between existing and new sources in these sectors will not occur (except for that accounted for by the

mobile source models). The references for the retirement rates are noted in Column H of the worksheet.

#### **5.2.4 Import Source Sector PM2.5 Speciation Factors**

As discussed elsewhere, the MAG base 1995 inventory reports the quantity of total PM-2.5 being emitted from the various sources, but does not provide information about the composition of the PM-2.5 emissions. Because the composition of particulate matter has a very significant effect on how the particulate matter affects visibility, a breakdown of the composition of the PM-2.5 emissions is needed. This information is contained in the tables imported in Tab 5.2.4. These tables are the Source Sector PM-2.5 Emission Speciation Factors used to convert the base 1995 emission inventory into the speciated inventory.

The source sector speciation factors were derived from either the emission inventory from the GCVTC, or from local Phoenix studies. The speciation profiles for diesel and gasoline engine exhausts were developed from an examination of a wide range of studies. The basic speciation factors contained in Tab 5.2.4 are referred to in Tab 3.6. Tab 3.6 also applies an additional correction to the basic speciation profiles to compensate for the discrepancy between the relative composition of organic and elemental carbon in the inventory compared to the filter measurements.

### **5.3 Control Efficiency Development Sheets**

One of the major undertakings in developing BCAT was the development of the control efficiencies to be used in the modeling. One of the basic ground rules in developing the BCAT was that the emission projections for 2003 and 2006 tie back to the emission projections from MAG provided in the PM-10 implementation plan. In addition, more extensive mobile source emission modeling would be needed for the proper treatment of the on-road mobile sources. Also, utility emission projections from Maricopa County needed to be based on the best and most recent information available for the utility source sector.

There was insufficient information at the source sector level to develop unique control efficiencies for existing and new sources within the source sectors. There was sufficient information to develop composite average control efficiencies for the forecast years that could be used to represent the existing and the new sources. The development of the control efficiencies relied on emission reference forecasts for some source sectors, and effective control efficiencies for most source sectors in the out years (2010-2020). In all cases the reference emission forecasts for 2003 and 2006 were used to derive control efficiencies for these years. The following is the sequence of the data analysis that led to the development of the composite control efficiencies.

#### **5.3.1 Reference Inventories (2003-2020)**

The 2003 and 2006 reference emission projections from the PM-10 implementation plan are contained in the first two 5.3.1 Tabs (5.3.1-MAG2003, 5.3.1-MAG2006). The

emissions for utility point sources in these Tabs were those developed by Maricopa County.

The emission projections for only mobile sources and utility point sources were contained in the next three Tabs (5.3.1-MAG2010 through 5.3.1-MAG2020). These emission forecasts will be used to determine the effective control efficiency compared to the 1995 base year. For the other source sectors, MAG provided projected control efficiencies, described below.

### **5.3.2 Assembled Baseline Reference Inventory**

The reference inventories were assembled into a worksheet (Tab 5.3.2) that had a column and row layout identical to the Baseline Forecast Scenario emission projection (Tab 4.1.5). Tab 5.3.2 was constructed by referring to the appropriate cells in the 5.3.1 tabs, and the reference 1995 emission inventory in Tab 5.2.1. If there were no data values in the reference inventories, the Tab 5.3.2 worksheet reports a zero emission rate for those cells. This is an artifact that is corrected when the control efficiencies are computed and merged. For reference the cell equations for the first source sector for PM-10 are:

Tab 5.3.2, Cell B12 (1995 PM-10): ='5.2.1-IMPORT\_MAG95'!B12

Tab 5.3.2, Cell C12 (2003 PM-10): ='5.3.1-MAG2003'!B12

Tab 5.3.2, Cell D12 (2006 PM-10): ='5.3.1-MAG2006'!B12

Tab 5.3.2, Cell E12 (2010 PM-10): ='5.3.1-MAG2010'!B12

Tab 5.3.2, Cell F12 (2015 PM-10): ='5.3.1-MAG2015'!B12

Tab 5.3.2, Cell H12 (2020 PM-10): ='5.3.1-MAG2020'!B12

### **5.3.3 Implied Control Efficiencies from Reference Inventory**

In order to compute the effective control efficiency for the BFS, a reference projected inventory assuming no change in control efficiency is needed. Changing all the control efficiencies to 1.0 (i.e., no change from 1995) in Tabs 3.9.1 and 3.9.2 can generate this emission projection in Tab 4.1.5 which is the BFS emission projection.

After the base control efficiencies have been altered as described above, the control efficiencies in Tab 5.3.3 reflect the calculated control efficiencies needed to match the emission projections in the reference inventory. In order to prevent division by zero problems, the following is the conditional calculation logic used to force the control efficiency to 1.0 unless the emissions in Tab 4.1.5 are greater than zero:

Tab 5.3.3, Cell C12 (2003 PM-10):  
=IF('4.1.5-BFS\_Emis'!C12=0,1,'5.3.2-BFS\_MAG\_REF'!C12/'4.1.5-BFS\_Emis'!C12)

#### 5.3.4 Inventory Adjustment for Effects of Tier-II Standards

One difficulty with the mobile source model used by MAG is that it failed to reflect the projected changes in emissions due to the Tier-II standards for on-road gasoline and diesel engines that were in effect in September, 2000 when the BCAT was initially developed. At that time, EPA was considering setting more restrictive Tier-II standards for diesel and heavy-duty gasoline engines and fuels, but since they had not been finalized, the emission improvement could not be considered in the Baseline Forecast Scenario, although it was assessed as a control option. (As will be discussed below in other sections, these new standards have been finalized, and the BCAT was modified to reflect their effect in the BFS). The adjustments for the earlier Tier-II standards are performed in Tab 5.3.4.

The Regulatory Impact Analysis of these Tier-II standards was reviewed to determine the projected change in mobile source emissions that would be expected under these new standards. These were expressed as a percent of MAG mobile source modeled emissions that will remain after the new standards are considered. The following summarizes the projected changes used in the adjustment to modify the MAG mobile source modeling results to reflect the effect of the Tier-II standards in effect in September, 2000:

<b>FRACTION OF NON-TIER II EMISSIONS REMAINING</b>	<b>Pollutant</b>	<b>2006</b>	<b>2010</b>	<b>2015</b>	<b>2020</b>
<b>On-Road Gasoline Mobile Sources - Fraction Remaining</b>	<b>PM-10</b>	<b>0.490</b>	<b>0.410</b>	<b>0.390</b>	<b>0.380</b>
	<b>PM-2.5</b>	<b>0.490</b>	<b>0.410</b>	<b>0.390</b>	<b>0.380</b>
	<b>NOX</b>	<b>0.797</b>	<b>0.590</b>	<b>0.390</b>	<b>0.290</b>
	<b>SOX</b>	<b>0.207</b>	<b>0.110</b>	<b>0.110</b>	<b>0.110</b>
	<b>NH3</b>	<b>1.000</b>	<b>1.000</b>	<b>1.000</b>	<b>1.000</b>
	<b>VOC</b>	<b>0.917</b>	<b>0.850</b>	<b>0.790</b>	<b>0.740</b>
<b>On-Road Diesel Mobile Sources - Fraction Remaining</b>	<b>NOX</b>	<b>0.884</b>	<b>0.740</b>	<b>0.650</b>	<b>0.610</b>

These values were developed in Tab 5.3.4 by interpolating the projected changes in the reference years contained in the EPA analysis (see Rows 160-169). These factors were then applied to the reference inventory in Tab 5.3.2 to develop a new reference inventory that included effects of the Tier-II standards. Note that these corrections were only applied to the on-road mobile source categories for the winter and annual projections. The relevant calculations for the cells are:

Tab 5.3.4, Cell B12 (cell not affected by change): ='5.3.2-BFS\_MAG\_REF'!B12

Tab 5.3.4, Cell B77 (Diesel on-road adjustment):  
=ROUND('5.3.2-BFS\_MAG\_REF'!B77\*B\$169,2)

Tab 5.3.4, Cell B78 (Gasoline on-road adjustment):  
=ROUND('5.3.2-BFS\_MAG\_REF'!B78\*B164,2)

As shown above, the adjusted values were rounded to the nearest hundredth of a metric ton per day of emissions.

### **5.3.5 Implied Control Efficiencies with Tier-II Standards**

After the reference inventory adjustment for Tier-II, the effective control efficiencies can be recomputed using the same method as used in Tab 5.3.3. Again the computations are based on the baseline emission forecast with no change in control efficiency over time as discussed in 5.3.3. The following is an example of the calculation performed:

Tab 5.3.5, Cell C12 (2003 PM-10):

=IF('4.1.5-BFS\_Emis'!C12=0,1,'5.3.4-BFS\_TIER2'!C12/'4.1.5-BFS\_Emis'!C12)

### **5.3.6 Imported Source Sector Control Efficiencies (2010-2020)**

In order to complete the development of the control efficiency tables, the reference control efficiencies for 2010 thru 2020 for the source sectors that were not computed above need to be organized. The three tabs 5.3.6-2010\_EFF through 5.3.6-2020\_EFF contain the projected effective control efficiencies for the source sectors other than utility point sources and on-road mobile sources. These were provided by MAG on the basis of their long-range forecasts.

### **5.3.7 Spliced Control Efficiencies (Tier-II and MAG Import)**

The computed control efficiencies from Tab 5.3.5 and the imported control efficiencies in Tabs 5.3.6 are combined into an overall control efficiency table in Tab 5.3.7. These tables reflect the combination of the best information available for effective control efficiencies (compared to the 1995 base year).

In order to discriminate the source of the data, the computed control efficiencies (all of 1995-2003, 2010-2020 for utility point and mobile sources) are displayed in a bold font. The imported control efficiencies are displayed in regular font. Upon initial examination, the developer will find “anomalies” in the data between the computed and the imported values for a given source sector. These are generally due to numerical precision limitations of the input reference emission inventories. Specifically, in cases where the emission rate is small, and there is no change in the displayed numerical values from time period to time period, there can be cases where the calculated control efficiency is off significantly from a reasonable value (i.e., value greater than 1.0 or significantly lower than the control efficiency imported for 2010-2020). Because of this a manual reconciliation of the control efficiencies is needed.

### **5.3.8 Control Efficiencies with Manual Adjustments for Consistency**

A copy of the worksheet in Tab 5.3.7 was prepared and adjusted manually for consistency. Manually altered values are displayed in italic font to show where changes were needed. This worksheet then became the basis for the final adjustments performed in Tab 5.3.9.

### **5.3.9 Frozen Control Efficiencies for Application and 2001 Tier-II Adjustment**

Originally, once Tab 5.3.8 was developed, a “frozen value” version of the worksheet was prepared in Tab 5.3.9. This then became the reference control efficiency table for both the existing and new sources (Tabs 3.9.1 and 3.9.2). After the values were fixed (copy entire sheet then paste special/values), the cells in Tabs 3.9.1 and 3.9.2 were edited to refer to the cells in 5.3.9. This then generated a finished BFS emission projection in Tab 4.1.5 that reflected these control efficiencies. Final adjustments to the values in Tab 5.3.9-BFS\_FROZEN\_CTLEFF were performed after examining the audit spreadsheet in Tab 5.3.10.

The approach taken to reflect the effect of the new Tier-II standards in the model was to directly adjust the control efficiencies previously developed in Tab 5.3.9-BFS\_FROZEN\_CTLEFF. This is done in Tab 5.3.9-BFS-2001-CTLEFF. The expected impacts of the new standards were derived from an examination of the Regulatory Impact Analysis for the proposed standard. The relative reduction for each pollutant for the diesel and diesel fuel standard was estimated from the RIA. A more detailed analysis for the heavy-duty on-road gasoline sources in the “Gasoline” source was performed to derive similar reduction estimates. These values were entered by source sector, pollutant, and forecast year below the annual average table in the tab, and the original frozen emission forecast was adjusted by the factors reflecting the new standards. The adjustment factors applied were:

<b>FRACTION OF PRE-2001 TIER II EMISSIONS REMAINING</b>	<b>Pollutant</b>	<b>2006</b>	<b>2010</b>	<b>2015</b>	<b>2020</b>
<b>On-Road Gasoline Mobile Sources - Fraction Remaining</b>	<b>PM-10</b>	<b>1.000</b>	<b>0.961</b>	<b>0.869</b>	<b>0.817</b>
	<b>PM-2.5</b>	<b>1.000</b>	<b>0.961</b>	<b>0.869</b>	<b>0.817</b>
	<b>NOX</b>	<b>1.000</b>	<b>0.986</b>	<b>0.945</b>	<b>0.920</b>
	<b>SOX</b>	<b>1.000</b>	<b>1.000</b>	<b>1.000</b>	<b>1.000</b>
	<b>NH3</b>	<b>1.000</b>	<b>1.000</b>	<b>1.000</b>	<b>1.000</b>
	<b>VOC</b>	<b>1.000</b>	<b>0.997</b>	<b>0.984</b>	<b>0.973</b>
<b>On-Road Diesel Mobile Sources - Fraction Remaining</b>	<b>PM-10</b>	<b>0.930</b>	<b>0.620</b>	<b>0.320</b>	<b>0.150</b>
	<b>PM-2.5</b>	<b>0.930</b>	<b>0.620</b>	<b>0.320</b>	<b>0.150</b>
	<b>NOX</b>	<b>1.000</b>	<b>0.860</b>	<b>0.480</b>	<b>0.270</b>
	<b>SOX</b>	<b>1.000</b>	<b>0.030</b>	<b>0.030</b>	<b>0.030</b>
	<b>NH3</b>	<b>1.000</b>	<b>1.000</b>	<b>1.000</b>	<b>1.000</b>
	<b>VOC</b>	<b>1.000</b>	<b>0.820</b>	<b>0.560</b>	<b>0.460</b>

### **5.3.10 BFS Audit for 1995, 2003, and 2006 Emissions and 2001 Tier-II Standards**

As a reference in the reconciliation process, an audit sheet comparing the September 2000 reference Tier-II emission inventory in Tab 5.3.4 with the emission projections in the BCAT BFS emission projection in Tab 4.1.5 is included as Tab 5.3.10-BFS\_AUDIT\_FROZEN. Since only significant differences are of interest, the calculation

logic in Tab 5.3.10 only displays differences that are greater than a tenth of a metric ton per day. Note that because of conflicts in the imported control efficiencies, and the application of Tier-II, all of the values are not expected to match. If the values match within this tolerance, the cell will be blank. If not, a value will be displayed showing the magnitude of the difference between the two emission inventories. The cell reference equation used is:

Tab 5.3.10-BFS\_AUDIT\_FROZEN, Cell B12:  
=IF(ABS('5.3.4-BFS\_TIER2'!B12-'4.1.5-BFS\_Emis'!B12)<0.1,"","5.3.4-BFS\_TIER2'!B12-'4.1.5-BFS\_Emis'!B12)

Again, upon reviewing the values contained in Tab 5.3.10-BFS\_AUDIT\_FROZEN, final adjustments to Tab 5.3.9 should be performed.

Two additional audit sheets were added for the final January 2001 Tier-II standard update. First, a tab was created of the BFS emission projections before the changes were made to the model (Tab 5.3.10-PRE2001\_BFS\_Emis). This sheet was then frozen for reference so the control efficiencies could be altered without changing these former values used for earlier assessments with the BCAT. The second sheet (Tab 5.3.10-BFS\_AUDIT\_2001) displays the differences between this old baseline forecast of emissions (before the 2001 final Tier-II) and after the changes had been applied for the new standards. The magnitude of the emission changes were verified to match those that had been achieved independently by running the 2001 final Tier-II standards as a control scenario.

## **5.4 Creating BCAT from BCAT DEVELOPER**

There will probably come a time when it will be necessary to update the BCAT to add or change information because of improved cost information, air quality modeling, control efficiencies, and/or to add additional source sectors. This section explains how to update the BCAT.

Whenever changes are needed to the BCAT, the change should be applied to BCAT\_DEVELOPER and then BCAT rebuilt from BCAT\_DEVELOPER. This is assuming that a simple change to both BCAT and BCAT\_DEVELOPER is more than is needed to fix the problem.

The smaller BCAT worksheet is created by freezing the values in the control sheets that refer to the imported data/development tabs described in this section. The tabs with cells that must be converted from “formulas” to “fixed values” (and thus frozen) include Tabs 3.5, 3.6, 3.7, 3.8, 3.9.1 and 3.9.2. Once these tabs have been converted to frozen values, all of the developer worksheets (5.1 through 5.3.10) can be deleted without affecting the calculations of the scenarios.

## 6.0 References

1. George, M., "Adjusting the emissions inventory for organic and elemental carbon," Arizona Department of Environmental Quality memorandum 206-10-4-2000, October 4, 2000. **Note: This document contains numerous additional references.**
2. Chow, J.C. et al., "The 1989-90 Phoenix PM10 Study, Volume II: Source Apportionment, Final Report and Appendices," Desert Research Institute Document Nos. 8931.6F1 and 8931.6F2, April 12, 1991.
3. Zielinska, B. et al., "Northern Front Range Air Quality Study Final Report, Volume B. Source Measurements," Desert Research Institute, June 30, 1998.



## **APPENDICIES**

### **Appendix A – Example Control Scenario**

The appendix to this report is a printout of a BCAT Excel file representing a control strategy analyzed for the Summit. The analysis of the scenario for “Voluntary replacement of airport ground support equipment” was used. The name of the Excel file matches that of the Scenario description.

The workbook should be printed as an entire workbook for relative page numbers to be in sequence, as opposed to printing the workbook out one worksheet at a time. This is done by selecting “workbook” from the print menu.

Filename: BCAT\_USERS\_GUIDE.doc  
Directory: M:\WPDOCS\TEMP  
Template: C:\WINNT\Profiles\sem\Application  
Data\Microsoft\Templates\Normal.dot  
Title: Analytical Framework for GBCS  
Subject:  
Author: Shawn B. Kendall  
Keywords:  
Comments:  
Creation Date: 1/15/01 5:56 AM  
Change Number: 25  
Last Saved On: 1/17/01 12:50 PM  
Last Saved By: DA1  
Total Editing Time: 499 Minutes  
Last Printed On: 1/23/01 1:54 PM  
As of Last Complete Printing  
Number of Pages: 61  
Number of Words: 21,638 (approx.)  
Number of Characters: 123,338 (approx.)